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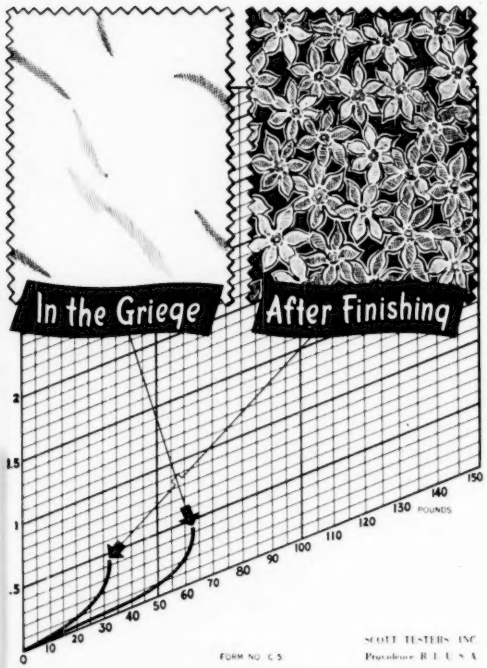

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TEXTILE RESEARCH JOURNAL

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Interpretation of the Mechanical Behavior of Rayon

L. Hermanne

Fabelta, Zwijnaarde, Belgium

(Translated from the French by Charles H. Lindsley, Charlottesville, Virginia)

The author of this paper is head of the Central Textile Laboratory of Fabelta (Union des Fabriques Belges de Textiles Artificiels). The Fabelta group includes all of the Belgian rayon and staple fiber mills. Several interesting points of view which may be new to many of our readers are presented. For example, the concept of the micro-Brownian movement of the cellulose chains in the amorphous regions, the thermodynamic point of view, and the equation of state for rayon. —Editor

Introduction

The present considerations are the fruit of reflections upon measurements* of the elastic and rheological properties of fibers, especially of viscose rayon. Giving a description of these measurements here would lead us too far afield, but in order to understand what follows it is necessary to emphasize the following points:

1. Tests of relaxation of tension after sudden elongation with apparatus of the type described by Polanyi [10] show that the rate of relaxation quickly diminishes and the tension asymptotically approaches a value greater than zero; and that because of this falling off in rate it is very difficult to express the tension as an analytic function of time.

2. Tests of deformation under constant load (in both wet and dry states) and tests of the reversibility of these deformations indicate that for a given load the elongation approaches an asymptote, and that in the wet state the reversible part of the deformation is very much greater than it is in the dry state. What is permanent deformation when the material is dry may even disappear upon wetting: the deformation, blocked when dry, permits tensions to persist that are revealed by moisture. Contrary to a generally held opinion, therefore, regenerated cellulose fiber possesses a cohesive skeleton even when moist. As a result, it is essential to examine closely the distinction between the elastic and the blocked part of the deformation.

3. The systematic study, by means of an electronic dynamometer, of differently stretched rayon fibers shows that the elastic limit σ_d, Young's modulus E_{elastic}, the modulus of permanent deformation $E_{\text{permanent}}$, and the breaking load of the filament increase, whereas the elongation at rupture

* Executed in the Textile Laboratory of Fabelta.

decreases when the stretching of xanthate is increased.

In what follows, no attempt is made to offer a complete presentation in which each detail receives its experimental proof. A working hypothesis is set forth, however, which leads to an understanding and an interpretation of these phenomena and which differs from the usual interpretations.

A. Phenomenological Point of View

The graph of load, σ, *vs.* deformation, γ, that is obtained by loading and unloading quasi-statically has significance for fibers in so far as they do not show plastic deformation. Our measurements have shown that there is only an extremely small amount of plastic deformation for fibers of regenerated cellulose hydrate. This point will be considered in detail later on. The curve σ *vs.* γ is very well suited to characterize the essential mechanical properties of fibers. It is of interest under several different conditions: first, in the dry state (*i.e.*, in normal atmosphere at 65% relative humidity); then in the wet state; and under immersion in liquids other than water and at varying temperatures. Figure 1 shows curves for an ordinary rayon when wet and when dry. The load, σ, is expressed in kilometers weight (kms.) of the fiber itself. (To convert to other common units, the load in kms. is multiplied by d, by $9.8 \times 10^5 d$, or by $1.9 d$, where d is the fiber density, to express it in kg/mm², dynes/mm², or g/denier, respectively.) As the unit of elongation, the relative length is used: γ = final length/initial length.

As the fiber is loaded, it stretches as shown by the portion of the curve AB; if after S is reached, the load is gradually reduced, the curve SL is traced. If the fiber is again loaded, the elongation follows the path LNT. The cycle may then be repeated, giving the dotted loop. The curves for unloading and reloading, SL and LNT, do not coincide because the quasi-static loading is never sufficiently slow in practice for final equilibrium to be perfectly attained. When the measurement is carried out more slowly the hysteresis loop becomes narrower.

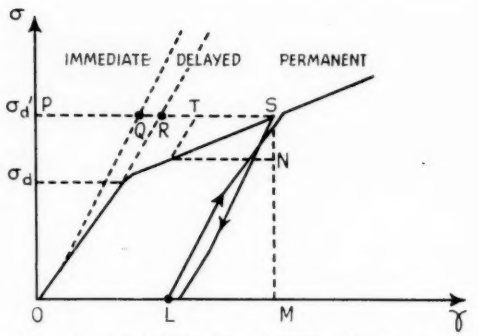

FIG. 2. *Load-elongation diagram for dry rayon. Three types of deformation are indicated: instantaneous elastic (immediate); delayed elastic (delayed); and permanent.*

1. Properties of the $\sigma - \gamma$ Curve for the Dry State

Three kinds of deformation may be distinguished. First, the instantaneous elastic deformation PQ (Figure 2), which is approximately proportional to σ and therefore follows Hooke's law. Second, the delayed elastic deformation QR; for a given rate of loading it also is nearly proportional to σ. The position of Q depends upon the rate of loading. For perfectly static methods, points Q and R coincide. The more quickly the sample is loaded, the larger the delayed part of the deformation and the further Q is displaced to the left. At acoustical frequencies, PQ is still finite. The delayed deformation is the cause of hysteresis and of dissipation of energy during oscillations, and appears as a

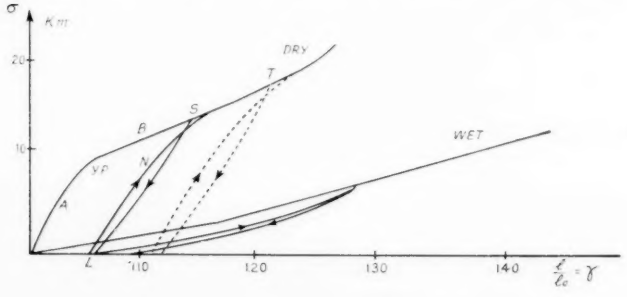

FIG. 1. *Load-elongation diagram for dry and moist rayon.*

FIG. 3. *Non-oriented cellulose (after Houwink).*

damping-out effect. From the geometry of Figure 2, it is seen that the permanent elongation RS is equal to LO and that the total elastic elongation PR is equal to ML. In the writer's experience there are no cellulose fibers for which PR exceeds 5%. In general there is only slight variation from this value among the different types of fibers.

The third type of deformation is permanent (RS or LO) and extends beyond the yield point (σ_d). For a given load it reaches a final value asymptotically with time. It is not a question of plastic flow, for then the deformation would proceed at a finite rate.

Other considerations support this point of view. Thus when a fiber previously loaded to point S is unloaded and then reloaded, no new permanent deformation occurs at σ_d but only beyond $\sigma_d' = S$. The threshold of deformation is therefore apparently raised from σ_d to σ_d'. This is the phenomenon of hardening. As further evidence, if a fiber which has undergone permanent deformation is moistened without tension, it regains its initial length. After drying, a new loading will again give permanent deformation beginning at σ_d, just as for the fiber initially. The deformation OL is not then plastic in nature but is *blocked elastic*. The return upon wetting indicates the presence of internal tensions. But the forces of regain are too weak to overcome the van der Waals' attractions between chains. The water that penetrates into the amorphous regions hides these polar forces. In order to give a detailed study of the mechanisms involved, it is important to express the curve σ *vs.* γ mathematically. A good first approximation is given by the expression:

$$\gamma - 1 = \frac{\sigma}{\text{modulus of elastic deformation}} + \frac{\sigma - \sigma_d}{\text{modulus of permanent deformation}}$$

where the modulus of permanent deformation is $\Delta\sigma$/permanent deformation or SN/TS. It is clear that the second term is zero for $\sigma < \sigma_d$. Depending upon the speed of measurement, the elastic

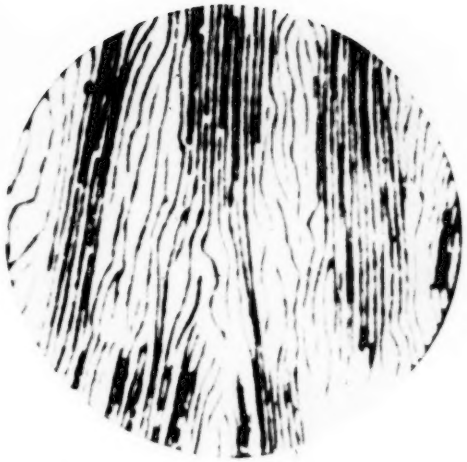

FIG. 4. *Oriented cellulose (after Meredith).*

elongation will include more or less of delayed elastic deformation, and thus the elastic modulus will lie between the acoustical modulus OP/PQ and the static elastic modulus OP/PR (Figure 2).

2. Properties of the $\sigma - \gamma$ Curve for the Wet State

In the wet state, the deformation at rupture is markedly greater than in the dry, and the deformation for a given load is also much greater; hence the modulus of deformation is lower. The curve is slightly concave to the σ-axis (Figure 1); in fact, the modulus changes over the entire length of the curve. The curve does not show a well-defined yield point. For decreasing load, the curve is similarly concave towards the σ-axis, but there is a very important hysteresis effect. There remains, however, only a very slight deformation when the load is completely removed; hence for a given deformation, the ratio of elastic to permanent deformation is definitely higher in the moist than in the dry state. Up to quite high loads—say, three-fourths of the breaking load—there is no plastic deformation (flow). To each tension there corresponds a definite ultimate deformation. However long the fiber is held at that load, rupture does not occur.

B. Relation to Structure

1. The Dry State

It is not enough to describe precisely the mechanical behavior of the fiber; it is also necessary

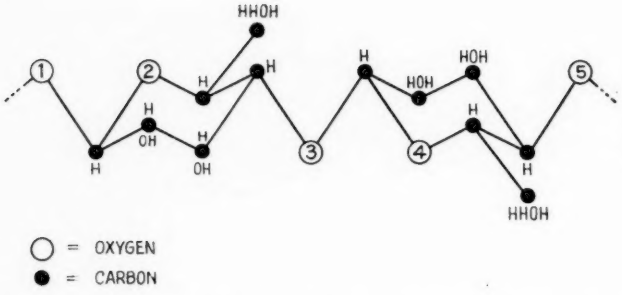

FIG. 5. *Perspective sketch of glucosidic nonplane rings as links in a cellulose chain.*

to given an explanation for it. In so far as possible, it is desirable to interpret the observed phenomena in terms of fiber structure. Regenerated cellulose hydrate consists, as is well known, of chainlike macromolecules arranged in part in crystalline regions and forming, for the rest, amorphous regions. In commercial fibers the ensemble is strongly oriented. R. Houwink [2] in 1937 represented the amorphous regions as in Figure 3, in which the lines represent the macromolecules. For oriented cellulose, the representation given by Meredith [5] in 1946 seems entirely satisfactory (Figure 4).

As the molecules are lined up together in the crystalline regions, they all resist simultaneously any deformation and show an appreciably higher resistance to a given deformation than do the amorphous regions. In the crystalline regions, deformation can only result from an increase of potential energy by an increase in the distance between atoms (either primary or secondary bonds) and by distortion of the valence angles. According to an estimate by Meyer and Lotmar [6], this mechanism can account for 2% of the elongation at rupture. The possibility that as much as 5% may be accounted for in this way should not be excluded, but, even so, the principal part of the elongation of regenerated cellulose takes place in the amorphous regions, *i.e.*, in the fringes of the enmeshed chains, which form a dense felt between the microcrystals.

In the amorphous regions the chains have a preferred orientation but are tangled together. On the one hand, the chains are held together by those among them that extend into a crystalline zone, by van der Waals' attractions between chains, and by hydrogen bonds between chains. On the other hand, thermal agitation tends to separate them. In fact, there exists freedom of rotation about the two valences of the oxygen atom that unites two glucosidic rings (Figure 5).

This freedom permits change of configuration of individual chains without any change in potential energy by modification of the statistical distribution of orientation of the glucosidic rings. It also permits modification of the relative arrangement of the chains. Nothing has been written on the subject of this micro-freedom of the cellulose chains in the amorphous regions. The chains may be regarded as a succession of relatively rigid parts (the glucosidic rings) bound together by the oxygen valences. These last have an angle of least energy of the order of 105°. The four valences of the carbon atom tend towards the tetrahedral angle (109.5°). The rings are often treated as planes; however, there is no reason to be dogmatic on this point. On the contrary, while the ring can easily be constructed without tension if not plane, it is impossible to make a tension-free plane glucoside ring. For the crystallized form, the recent communications of Meyer and Van der Wijk [8] and of Peirce [9] based on x-ray examination give a configuration similar to that in the scheme of Figure 5.

We may now consider the assembly of links to form a chain. From the geometrical viewpoint, one may describe such a link as the axis C_1C_4 of the glucoside ring (Figure 6) with the valence bonds C_1O_1 and C_4O_3 forming definite angles on C_1C_4. On this basis we say that the first link goes from O_1 to O_3, the second from O_3 to O_5, the third from O_5 to O_7, etc.

What are the possible relative directions of the axes O_1O_3, O_3O_5, and O_5O_7? For purpose of discussion, the first link may be assumed to be fixed in space. The oxygen atom O_3 seeks the angle of least energy between its valence directions—

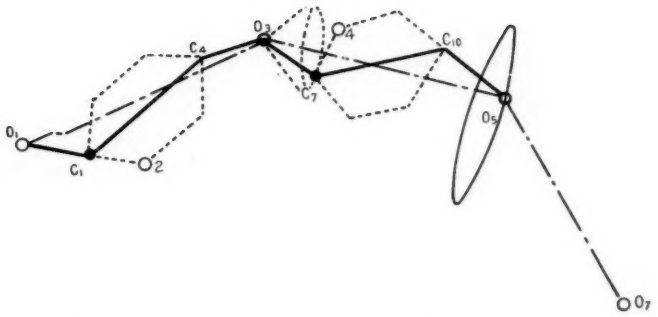

FIG. 6. *Combination of glucosidic rings to form cellulose chains, showing free rotation about oxygen valences.*

namely, 105°. The C_7 atom then possesses minimum potential energy when it lies somewhere on the dotted circle. Once it has taken its position, atom O_5 may still choose among all positions on the solid circle, since $O_5O_3C_7$ forms a fixed angle. The combination of these two freedoms permits a double infinity of positions of equal energy at O_5. The next glucosidic group determined by the axis O_5O_7 is similarly mobile with respect to the second group (O_3O_5). In the cellulose chain there exists a certain freedom of orientation of the links, and thermal agitation tends to establish the most probable statistical distribution. In nonoriented material the axes (*e.g.*, O_1O_3) are dispersed in all directions. The entropy S of the system is a function of the probability of distribution as given by the Boltzmann relation $S = k \ln P$, where k is Boltzmann's constant and P is the probability. For rubber, a similar mechanism results in elongations up to 800%. For cellulose, the mobility of the chain is less, so that very much smaller elongations are possible. Actually, in the nonoriented state 300% is rarely exceeded.

The rayons are strongly oriented, owing to the stretching (of the order of 200%) which they have received. Hence the limit of deformation is below 50%.

The above concept permits explanation of mechanical behavior in terms of structure—something which has not been achieved until now. It would be interesting to carry out the calculations involved. To this end, the entropy S must be expressed in terms of the probability of distribution of the orientation of chain links.

For the entropy of rubber, several authors have undertaken the task. They have had to make a series of assumptions leading to expressions which differ according to those assumptions. All of them, however, give a modulus that depends upon the number of links that pass through unit cross section, a result not in very good agreement with experiment. The case of rubber is much simpler than that of cellulose, for the links are simple and similar, there is only one degree of freedom, and there are few attractions between chains.

For cellulose, there still exist several unresolved points, such as the interaction between chains—*i.e.*, the process of transmission of tension between chains and also between crystalline areas. Here two more cases arise: one, at the moment of spinning; the other, after fixing—*i.e.*, in the true fiber. A further unresolved point is the variation in the distribution of orientation from chain to chain. Actually, the tension is not equally distributed among all chains, but is supported mainly by those which are least deformable, in which orientation is most advanced. Accordingly, the entire load is supported almost exclusively by these chains, and the modulus of the fibers corresponds only to the reaction of a part of the chains.

The theory ought to furnish an estimate of the proportion of chains which share in supporting the stress. It is clear that, in the present state of our knowledge, there are too many possible hypotheses, any one of which might serve as the basis for calculation. Thus an erroneous principle might lead to results which appear to be in reasonably satisfactory agreement with observation, and consequently it is premature to pursue such calculations further at this time. It is of considerable interest to note that W. Kuhn [3] has shown that a chain of which the links possess only incomplete mobility gives the same effect as a chain of longer "statistical" links disposed with complete mobility.

FIG. 7. *Schematic representation of a cellulose chain and symbolization of thermal agitation by arrows.*

2. The Wet State

In the dry state, which has just been considered, the freedom of the chains in the amorphous regions is limited by the attractions between chains, particularly by the hydrogen bonds, which probably are formed during the regeneration of the hydrate at the expense of the xanthate at the end of the spinning process, and by van der Waals' forces. The thermal agitation of a chain extends at most from one crystallite to the next, and for that reason the movement is called micro-Brownian.

In the wet state, water molecules penetrate into the amorphous regions and reduce the van der Waals' forces between chains in such a way that the mobility is increased. The deformability is markedly increased and, even for very weak loads, tends to exceed by far the deformation due to energy mechanisms. The entropy mechanism depends upon thermal agitation, which is chiefly transverse to the chain when orientation is pronounced (Figure 7). But the "Brownian energy" is of lower order than the energies involved in deformation of the valence bonds, and the elongation is obtained with a lower modulus (ratio of tension to deformation) than corresponds to the share in the elongation contributed by the energy mechanism. But when it is a question of recovery from the deformation upon unloading, it is difficult to restore the transverse thermal movement and to bring the fiber back to its original dimensions. Hystersis is then significant, and the elongation corresponding to each load is much higher during unloading than during loading (Figure 8A). The unloading follows the path of least energy. For this reason, the mechanism is not reversible in the dry state, since the barrier arising from the van der Waals' forces cannot be overcome. In the moist state, however, the mechanism is reversible because the water weakens these obstructing lateral attractions.

The graph of σ *vs.* γ for stretched vulcanized rubber (Figure 8B) is quite similar to that for moist cellulose. It also is concave towards the σ-axis, in contrast to the curve for dry cellulose, and the deformations are reversible to a very large degree, with a large hysteresis on unloading. While it is granted that the water of swelling reduces the van der Waals' attractions, it has no effect on the hydrogen bonds, which assure the cohesion of the structural network up to considerable tensions, so that it does not show any flow. In its mechanical behavior, the network of rayon is entirely comparable to that of vulcanized rubber, in which sulfur bonds (Figure 9) play a role analogous to that of hydrogen bonds in cellulose [7]. There is, nevertheless, a quantitative difference in the dimensions of the links, in the amount of freedom, and in the degree of orientation of the links. These differences result in an elongation much greater for rubber than for moist cellulose.

In all these considerations a valuable argument is found in favor of the concept of entropy mechanisms in cellulose.

3. Other Conditions

The present view of the mechanical behavior of rayon can be applied without difficulty to other forms of cellulose such as xanthate and ramie. As to the former, when all attractions between chains disappear, a cohesive network no longer

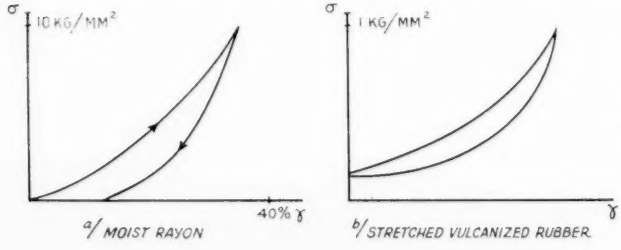

FIG. 8. *Load-elongation diagram for (a) moist rayon and (b) stretched vulcanized rubber.*

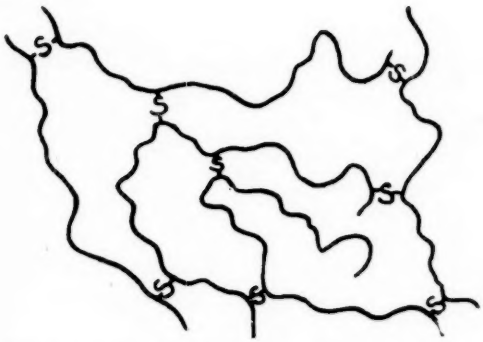

FIG. 9. *Sulfur bridges between molecules formed in rubber during vulcanization.*

exists and the material can undergo plastic deformation. In this case, an entire chain may be brought into thermal agitation, and the movement is called macro-Brownian. When swelling is pushed still farther, there is a gradual transition to a viscous solution (viscose). In this case, the macro-Brownian movement that is present restores, after a lapse of time, the most probable distribution of orientation of the links. So long as the network does not cohere, one can increase the order and the orientation by stretching, theoretically up to an ideal state, so that, during spinning, stretching in the xanthate form brings about an increase in solidity of the fibers. But once the network has become cohesive through formation of hydrogen bonds, one chain is stretched more quickly than another, resulting in internal tensions within the material, and further

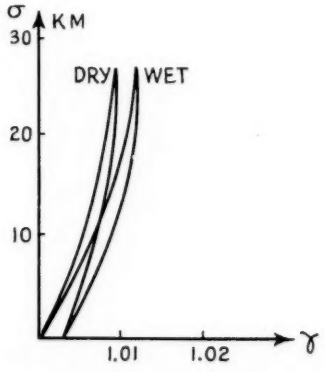

FIG. 10. *Load-elongation diagram for flax and ramie.*

improvement in the breaking strength is very small.

The fibers of flax and ramie contain little amorphous matter. Their graphs (Figure 10) are characterized by very small elongations, nearly the same in both the wet and the dry state. There is no yield point. Little deformation is found, therefore, attributable to the mechanism of entropy of orientation of the links. The permanent elongation is less than 1%, compared to about 20% for rayon; the elastic elongation is lower but not in the same ratio. The potential energy mechanisms, enclosed within the crystalline regions, act with a greater modulus because of their coordination. In this laboratory a modulus of elastic deformation of 10^{11} dynes/cm^2 was measured. Potential energy deformation obtained by twisting and stretching the valence bonds of these fibers is similar to that for regenerated cellulose. Before discussion of the combination of entropy and energy mechanisms, it may be well to insert a discussion of the combination of mechanisms in general.

C. Thermodynamic Point of View and the Equation of State

1. Analogy Between Mechanical and Electrical Coupling, in Series and Parallel Arrangement

A very strong analogy exists between the branching of electrical resistances in series and parallel and the coupling of mechanical units such as springs. Table I summarizes the points of similarity. The laws of Ohm and Hooke lead to entirely analogous rules for combinations of ele-

TABLE I. ANALOGY BETWEEN ELECTRICAL AND MECHANICAL COUPLING, IN SERIES AND IN PARALLEL

Electrical coupling	Mechanical coupling
Intensive dimension: V = voltage	σ = tension
Extensive dimension: I = current	γ = deformation
Characteristic: $R = V/I$ = resistance	$E = \sigma/\gamma$ = Young's modulus

Combinations

	Series	Parallel
Case I	$I = I_1 = I_2 = V_1/R_1 = V_2/R_2$	$\gamma = \gamma_1 = \gamma_2 = \sigma_1/E_1 = \sigma_2/E_2$
	$V = V_1 + V_2$	$\sigma = \sigma_1 + \sigma_2$
	$R = V/I = R_1 + R_2$	$E = \sigma/\gamma = E_1 + E_2$
Case II	Parallel	Series
	$I = I_1 + I_2$	$\gamma = \gamma_1 + \gamma_2$
	$V = V_1 = V_2 = R_1 I_1 = R_2 I_2$	$\sigma = \sigma_1 = \sigma_2 = E_1\gamma_1 = E_2\gamma_2$
	$I/V = 1/R = 1/R_1 + 1/R_2$	$\gamma/\sigma = 1/E = 1/E_1 + 1/E_2$

ments. It should be noted that electrical connection in series leads to formulas analogous to those for mechanical coupling in parallel (Case I) and *vice versa* (Case II). In the first case, the potentials V and tensions σ are additive, and the characteristics, resistance R and modulus E, are likewise additive. The current I and the deformation γ of the combination are each equal to the corresponding quantity for each component. In the second case, on the contrary, the potential or tension of the combination and that of the individual components are equal. The current or the deformation of the combination is equal to the sum of the individual quantities. The relation for resistance and modulus is more complex:

$$R = \frac{1}{1/R_1 + 1/R_2} \quad \text{and} \quad E = \frac{1}{1/E_1 + 1/E_2}.$$

2. Combination of Energy and Entropy Mechanisms

By reference to this analogy, it is now possible to complete the deformation of entropic nature (see section *B-1*) by addition of the deformation arising from energy mechanisms of the kind met with particularly in the case of ramie (*B-3*). Change in entropy resulting from change in orientation of the links is not the only type of deformation that occurs in rayon. Furthermore, each link elongates by stretching of the valences and the deformation of their directions in making up the potential energy.

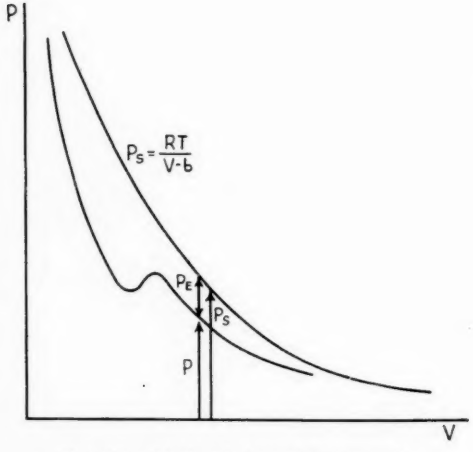

FIG. 11. *Ideal and observed pressure of a gas as a function of volume.*

Meyer and Lotmar [6] calculated the force required to deform a flat cellulose ring. The modulus is of the order of 10^{11} dynes/cm², *i.e.*, the upper limit that is rarely attained by cellulose. The elongation at break is in the neighborhood of 2%. The model shown in Figure 5, which is not flat, is more easily deformed, and an elongation of about 5% at rupture is predicted. It is easy to visualize how the two mechanisms may be combined. In the first place, within a single chain, the total deformation is, to a first approximation, equal to the sum of the elongations of the links increased by the elongation due to increase in orientation:

$$\gamma_{\text{chain}} = \gamma_{\text{energy}} + \gamma_{\text{entropy}}.$$

The two mechanisms are in series and are subject to the same total tension: $\sigma = \sigma_{\text{energy}} = \sigma_{\text{entropy}}$. In the second place, with respect to interaction between chains, one can likewise picture an energy mechanism and an entropy mechanism (entropy of crowding). It is not so easy to see how the latter enters into the combination. The energy mechanisms are limited to secondary (van der Waals') valences, and, in accord with the view of H. Mark [4], cannot account for more than 1% of the elongation. Practically nothing is known about the entropy of crowding.

It is therefore logical to admit that for the combination the principal part of the elongation is supplied by the chains, especially by addition of γ_E and γ_S. The role of the secondary valences is limited to a restraint upon the mobility.

This way of regarding the problem is in good agreement with the observed properties: the graph of σ *vs.* γ for the dry state (Figure 1) is linear and reversible up to the yield point (γ_E). With γ_S also operative, the graph continues less steep but still

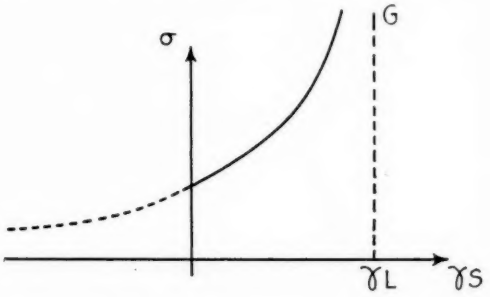

FIG. 12. *Modified load-elongation diagram for rayon.*

straight, to a fair approximation; on unloading, a curve is obtained which is parallel to the first portion, since γ_E alone is reversed and since the weak restoring forces of the entropy mechanism do not succeed in overcoming the van der Waals' forces in the dry material. Finally, during a new loading, it is necessary to exceed the loads previously reached before further orientation occurs (hardening). Likewise, the yield point gives evidence of the presence of an orientation which arises from the stretching exerted in the xanthate during spinning and fixed during the regeneration process. This orientation has been obtained with smaller forces and produces at once greater equalization of orientation of the different chains, with the desirable result that tenacity is increased. The equation for deformation may therefore be written:

$$\gamma = \frac{\sigma}{E_{\text{energy}}} + \frac{\sigma - \sigma_d}{E_{\text{entropy}}},$$

in which the moduli are represented by E. The second term is zero for $\sigma < \sigma_d$. The first term gives the elastic elongation; the second the blocked elastic, beginning at the yield point.

The form of the combination $\sigma = \sigma_{\text{energy}} + \sigma_{\text{entropy}}$, corresponding to a parallel coupling, as given in the recent literature (H. Mark [4] and P. H. Hermans [1]), in my opinion does not allow a coherent interpretation to be made. Actually, the rayons exhibit, in the dry state, some 20% deformability, of which 5% is instantaneous elastic. In the wet state, elongations reach 30%, to a large degree reversible, while the energy mechanism can reach only 5%. The question arises, what takes place after this 5% is exceeded? In the dry state, beyond the yield point, the fiber is less hard, so that, on the present hypothesis, the first mechanism may be supposed to be eliminated. But on unloading, the curve is parallel to the first part of the $\sigma - \gamma$ curve (Figure 1); hence it is necessary to consider the first mechanism. And when the loading is repeated, why should this first mechanism be assumed to fail only for tensions above T?

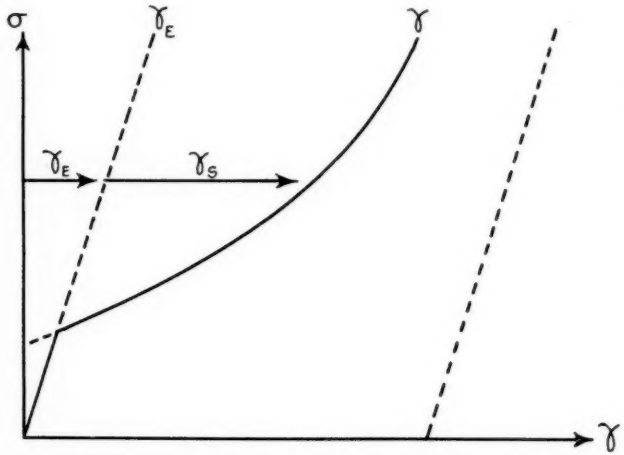

FIG. 13. *Further modification of load-elongation diagram for rayon.*

3. *Thermodynamic Point of View*

We have now identified, term by term, the experimental relation $\gamma = \gamma_{\text{elastic}} + \gamma_{\text{entropy}}$ with the structural expression. A further correspondence may be found with thermodynamic equations. The first law may be written in the form

$$dU = \delta Q - \delta A, \qquad (1)$$

where U is the internal energy, δQ is the heat contribution, and δA is the work done by the system, *viz.*:

$$\delta A = pdV \text{ for a gas, } = \sigma d\gamma \text{ for fibers,} \qquad (2)$$

σ and γ being taken as positive from the point of view of the system, by analogy to the case of gases; the pressure p in a gas is taken positive in the direction in which it acts, namely, increasing the volume; the tension σ in a fiber is taken positive in the direction of contraction; the variation in volume of a gas is taken positive as increase in volume; the variation in length of a fiber is taken positive as increase in length.

Enthalpy is introduced by the relation

$$H = U + \sigma\gamma. \qquad (3)$$

By differentiation,

$$dU = dH - \sigma d\gamma - \gamma d\sigma. \qquad (4)$$

From the second law,

$$TdS = \delta Q = dU + \delta A. \qquad (5)$$

By substitution for dU from equation (4) and for δA from equation (2), it follows that

$$TdS = dH - \gamma d\sigma \quad \text{or} \quad dH = TdS + \gamma d\sigma. \qquad (6)$$

The thermodynamic potential Z is defined by the relation:

$$Z = U - TS + \sigma\gamma = H - TS; \qquad (7)$$

whence, by differentiation,

$$dZ = dH - TdS - SdT. \qquad (8)$$

From equation (6) it follows that

$$dZ = \gamma d\sigma - SdT,$$

and therefore

$$\gamma = \left(\frac{\partial Z}{\partial \sigma}\right)_T.$$

From equation (8),

$$\gamma = \left(\frac{\partial H}{\partial \sigma}\right)_T - T\left(\frac{\partial S}{\partial \sigma}\right)_T.$$

By use of the Boltzmann relation $S = k \ln P$, where P is the probability of state, the following relation is finally obtained:

$$\gamma = \left(\frac{\partial H}{\partial \sigma}\right)_T - \frac{kT}{P}\left(\frac{\partial P}{\partial \sigma}\right)_T. \qquad (10)$$

The second term is positive: when σ increases, P decreases, and the negative value of the differential $(\partial P/\partial \sigma)$ reverses the sign of the whole term. Thus beyond the yield point a positive increment in elongation arises from this term.

4. Equation of State for Rayon

A van der Waals' gas differs from an ideal gas by the appearance of a term that takes account of the potential energy in addition to the entropy. Rayon stands in a similar relation to rubber, in which the entropy effect is found almost exclusively. While in the amorphous regions of cellulose the deformation due chiefly to entropy is decidedly smaller, there appears, in addition, an increment in the elongation due primarily to deformation of the links through increase in potential energy.

The equation of state for an ideal gas is $p = RT/V$, where the pressure p is entirely an entropy effect. For a van der Waals' gas, $p = RT/(V - b) - a/V^2$, where b is a correction for the volume of the molecules themselves, and the term a/V^2 is the difference between the observed and the theoretical pressure, due to the mutual attractions of the molecules. The term $RT/(V - b)$, therefore, is like an "entropy pressure" p_S, while the correction term $-a/V^2$ is an "energy pressure" p_E (negative). Figure 11 shows the ideal pressure p_S and also the observed pressure $p = p_S - p_E$. It has been shown that, for cellulose, it is not the tension that can be divided into energy and entropy portions, but rather the elongation, the observed elongation γ being expressed thus:

$$\gamma = \gamma_S + \gamma_E.$$

In order to set up in principle the equation of state for rayon, we shall take as the starting point the curve that expresses γ_S as a function of σ. For simplicity, we shall draw it as an hyperbola (Figure 12). In applying it to numerous measurements, this will permit us to determine the exact function, which could well be as complicated as the Langevin function. Furthermore, it will be convenient later on to substitute for the constants of this equation functions of time in order to tie in the rheological behavior and to take into account the additional dimension, time. The hyperbola adopted in order to arrive at the equation of state in principle is given by the equation:

$$\sigma(\gamma_L - \gamma_S) = \text{constant} \times T.$$

On the right is a constant multiplying temperature, corresponding to the nature of entropy. This constant is an undetermined function, with the same dimensions as the gas constant. It depends upon the mobility of the chain links, on their length, and on the ratio of amorphous to crystalline material. The limit γ_L of deformation must have physical meaning in relation to complete orientation. It now becomes a question of passing from the entropy deformation γ_S in the above equation to the observed deformation $\gamma = \gamma_S + \gamma_E$:

$$(\gamma_L - \gamma + \gamma_E) = \text{constant} \times T,$$

or

$$\gamma = \gamma_E + \gamma_L - \text{constant} \times T/\sigma.$$

This expression corresponds to the thermodynamic equation (10):

$$\gamma = \left(\frac{\partial H}{\partial \sigma}\right)_T - \frac{kT}{P}\left(\frac{\partial P}{\partial \sigma}\right)_T.$$

Finally, the curve σ *vs.* γ appears as in Figure 13, where the breakdown of γ into two parts, γ_E and γ_S, is shown.

5. Stretching, Orientation, and Formation of the Fiber

It is known that in spinning, viscose rayon passes through different stages. First, a filament of

viscose arrives in the acid bath through a fine orifice in the spinneret; this contact very rapidly coagulates a thin skin about the filament. Second, the solvent dialyzes across this skin, precipitating the xanthate. Third, the xanthate reacts with the acid which dialyzes through the skin and is transformed into the hydrate (fixation). The regenerated hydrate is still very much swollen (several hundred percent). Fourth, the ability to swell gradually diminishes, principally through drying, and the final fiber retains an ability to swell about 100%. In the course of the third and fourth stages, there is a possibility of the formation of hydrogen bonds, and the process of drawing favors such formation.

There is an essential difference between the results of drawing before and after fixing—*i.e.*, drawing the xanthate and the hydrate. In the first case the material is plastic, and drawing causes a slipping of chains over one another. This slipping orients the chains without relieving the stresses. It also equalizes the orientation of chains because the most oriented ones are the slowest to increase their degree of orientation and are simply slipping. For this reason the chains coordinate better among themselves, and the tenacity increases along with the moduli E_{elastic} and $E_{\text{permanent}}$. In the second case, after fixing, there exists a cohesive network (Figure 14; to be compared with Figure 9), and stretching does not entail any further slipping of entire chains. Thus, when the force is sufficient to constrain the orientation to a higher degree, beyond the yield point there is a rapid increase in orientation of certain chains, particularly those that are best oriented and cannot quickly orient themselves further, with the result that tensions increase greatly. These tensions are not evenly supported by the assemblage of chains. The distribution of the load is the less favorable to the extent that the degree of orientation shows more scattering. When the most highly oriented chains reach their breaking tension, they have attained some 5% elongation by potential energy change and begin to break. The load is taken up by the next chains, which soon break, and the rupture of the fiber follows by "statistical progression."

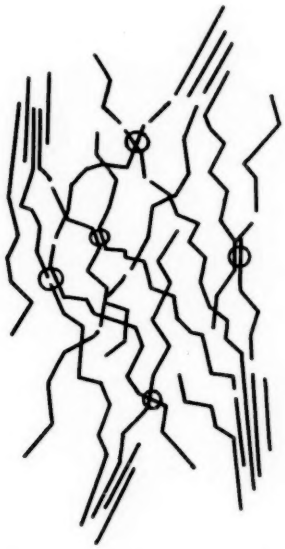

FIG. 14. *Schematic arrangement of chains in rayon after fixing.*

To return to the yield point, σ_d at that point may be regarded as a measure of the orientation present, fixed by the hydrogen bonds. Nevertheless, when the dry fiber suffers a stress greater than this value σ_d, the additional entropy deformation is not resorbed after unloading. Consequently, there remains a certain amount of orientation (hardening) which is shown by the apparent increase in yield value, and tensions persist within the network. Therefore, drawing after fixing does not increase the tenacity appreciably, in contrast to drawing in the xanthate state, which increases not only the tenacity but also the two moduli of deformation.

Summary

The working hypothesis here proposed permits analysis of the essential mechanical properties of cellulose by means of structural elements corresponding to physical reality.

1. The mechanical properties of rayon are principally related to the amorphous regions.

2. In these regions there are hydrogen bonds which, after regeneration, unite the chains into a cohesive network. In the xanthate state the chains can slide over one another.

3. The chains are made up of links and can elongate either through increase in potential energy by twisting and stretching the valences of the links (maximum elongation 5%), or by modification of the statistical distribution of the orientation of links, associated with a decrease of entropy

related to the probability of state, through thermal agitation (micro-Brownian movement).

4. The deformation γ can be resolved into two parts, γ_{energy} and $\gamma_{entropy}$, namely, $\gamma = \sigma / E_{energy} + (\sigma - \sigma_d) / E_{entropy}$. The first term corresponds to the elastic elongation in the dry state; the second to the permanent elongation (blocked elastic) which begins at the yield point. This resolution corresponds therefore to the phenomenological analysis:

$$\gamma = \gamma_{\text{reversible elastic}} + \gamma_{\text{blocked elastic}},$$

or

$$\gamma = \sigma / E_{\text{reversible elastic}} + (\sigma - \sigma_d) / E_{\text{blocked elastic}}.$$

5. This last relation becomes, in thermodynamic terms:

$$\gamma = \left(\frac{\partial H}{\partial \sigma} \right)_T - \frac{kT}{P} \left(\frac{\partial P}{\partial \sigma} \right)_T,$$

where H represents the enthalpy and P the probability of distribution of orientation. Finally, it can be expressed as an equation of state, analogous to van der Waals' equation. Thus cellulose bears a relation to rubber similar to that which a van der Waals' gas bears to an ideal gas.

6. The mean orientation of chains in the amorphous regions and the scattering of this orientation are essential for the mechanical behavior of the fiber. Stretching before fixing results in increased orientation and reduced scattering. This in turn increases the two moduli because the direction of the chain links becomes more effective; the chains are better coordinated, and further increase in orientation is less probable (the number of possible configurations is reduced). Stretching before fixing also increases the breaking strength and the yield value. This is the tension σ_d at which a stronger constraint begins to be imposed on orientation. Stretching after fixing increases σ_d and, slightly, the modulus E_s, without modification of the other characteristics, because no redistribution of tension occurs among the chains which are held within the cohesive network.

7. In the wet state, the mobility of the parts of the chains is so greatly amplified that the entropy mechanism contributes significantly to the elongation beginning with the smallest loads, and the modulus in the wet state is of the same order of magnitude as the blocked elastic modulus in the dry state.

Acknowledgment

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Literature Cited

1. Hermans, P. H., *J. Polymer Science* **1**, 389–92 (1946).
2. Houwink, R., "Elasticity, Plasticity, and Structure of Matter," Cambridge, The University Press, 1937.
3. Kuhn, W., *Experimentia* **1**, 6–18 (1945).
4. Mark, H., and Press, J., *Rayon Text. Mo.* **24**, 297–9, 339–41, 405–7 (1943).
5. Meredith, R., *J. Text. Inst.* **37**, P469–80 (1946).
6. Meyer, K. H., and Lotmar, W., *Helv. Chem. Acta* **19**, 68–86 (1936).
7. Meyer, K. H., and van der Wijk, A.J.A., *Experimentia* **2**, 117–26 (1946).
8. Meyer, K. H., and van der Wijk, A.J.A., *J. Polymer Sci.* **2**, 583–92 (1947).
9. Peirce, F. T., *Trans. Faraday Soc.* **42**, 560–71 (1946).
10. Polanyi, M., *Z. Tech. Phys.* **4**, 121 (1925).

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Transmittance, Reflectance, and Absorptance of Near Infrared Radiation in Textile Materials

Richard H. Wilhelm * and James Boyd Smith †

Contribution of the Department of Chemical Engineering, Princeton University, and the Textile Research Institute, Princeton, New Jersey

Abstract

This paper deals with the measured transmission of infrared energy with a wave length maximum at 9,700 Ångstrom units through layers of textile fabrics. A theory of transmission based upon Stokes' equations for the optics of a pile of parallel plates was found to describe the experimental data for textile fabrics satisfactorily. The theory also leads directly to reflectance and absorptance formulas which make possible the estimation of these properties from constants evaluated in transmittance measurements. The optical relationships are not limited to infrared radiation, but their application in this wave length range is of interest in radiation drying and in the comfort qualities of clothing.

Measurements were made on cotton, viscose rayon, cellulose acetate rayon, and woolen and worsted materials. In the case of some of these materials, especially woven fabrics of different weights were used. An R-40 lamp was used as an infrared source and a thallium sulfide photoconductance cell was used as the detector. Variables included nature of fiber, thickness of textile pile, weight and construction of fabric, moisture content, and presence of dyes.

For each material and for each condition, the transmittance was measured for successive layers of fabric piled one upon the other until the limit of sensitivity of the detector was reached. In some cases, transmission measurements were made to values as low as 0.0002 fraction transmittance. The experimental results are presented as the logarithm of transmittance versus thickness of fabric pile, expressed as weight per unit area.

It was found that the nature of the fabric fiber affected transmittance, that construction of the fabric did not, and that the important variable was the average number of fibers in the path of illumination. It was found also that transmittance increased to a maximum value and then decreased as the moisture content of the fabrics was increased from dryness to a high value. Finally, it was found that dyes markedly affected transmittance, with an enormous decrease for a sulfur black dye.

Quantitatively, the transmittance, I_t/I_o, was related to the thickness of path, w (in grams per square meter), to a constant, α (the reflectance of an infinitely thick layer of fabric), and to an extinction coefficient, k, in the following equation:

$$\frac{I_t}{I_o} = \frac{(1-\alpha^2)e^{-kw}}{1-\alpha^2 e^{-2kw}}.$$

The parallel equations for reflectance, I_r/I_o, and absorptance, I_a/I_o, are:

$$\frac{I_r}{I_o} = \frac{\alpha(1-e^{-2kw})}{1-\alpha^2 e^{-2kw}}$$

and

$$\frac{I_a}{I_o} = \frac{(1-\alpha e^{-kw})(1-\alpha)(1-e^{-kw})}{1-\alpha^2 e^{-2kw}}.$$

The two arbitrary constants, α and k, may be determined experimentally from either transmittance or reflectance or from absorptance measurements and applied to compute the other two properties. In the present work it was convenient to measure transmittance.

Equations also have been developed for the transmittance, reflectance, and absorptance of fabrics when supported by a surface having a reflectance, β, with values for β between 0 and 1.0.

THIS WORK was stimulated by a study of the radiation drying of textile materials [10] in which it was observed that radiant energy penetration appeared to take place during the course of drying. As a result, it seemed desirable to study the optics of infrared radiation in various textile materials independent of the complications of the drying process. The transmittance, reflectance, and absorptance of radiation are of interest also in the comfort qualities of clothing, particularly for wear at extremes of temperature. Studies of the effect of dyes on textiles frequently involve a consideration of the effect of the dye on the optical properties of the dyed material, particularly its reflectance. There are possibilities of placing quality characteristics of textile materials, such as sheerness, luster, and dullness, on a quantitative basis through a knowledge of textile optics. The behavior of light or radiant heat is of interest also in other materials, which, like textiles, are in the form of sheets and are composed of particles or strands which scatter light.

This paper reports the study of the transmittance of near infrared radiation, with a wave length maxi-

* Professor of Chemical Engineering, Princeton University.
† Fellow of the Textile Research Institute, March, 1946, to May, 1947. Present address: Permutit Company, 330 West 42nd Street, New York.

mum at 9,700 Ångstrom units, through layers of textile materials. Measurements were made on cotton, viscose rayon, acetate rayon, and woolen and worsted materials. In the case of the acetate rayon, viscose rayon, and woolens and worsteds, especially woven cloths of different weights were used. An R-40 lamp was used as an infrared source and a thallium sulfide photoconductance cell was used as the detector. Variables included thickness of the textile pile, weight and construction of fabric, moisture content, and the presence of dyes. A theory was devised based upon a direct analogy between multiple layers of reflecting and absorbing plates and multiple layers of textile materials, each unit layer consisting of a unit weight of material per unit area. The reflectance of a supporting surface also is considered in the formulas for over-all reflectance, absorptance, and transmittance.

The number of publications in the field of the absorption and transmission of radiant energy by textiles is limited. An early work was that of Gregory [5], in 1930, on the optics of textile materials using a water calorimeter as the measuring gage. A recent paper on the intensity of light reflected from a pile of dyed fabrics by Preston and Tsien [11] presented both theory and experimental data. These workers also used the model of a pile of plane parallel plates but introduced certain approximations in order to obtain an explicit relationship. Because of simplifying assumptions, their equation for reflectance for an infinitely thick pile of fibers is not applicable to white fibers but only to dyed ones. Their equation was used as a tool in a dyeing study. An excellent review of the literature is presented in the report by these authors.

A paper by Stearns [14] deals with infrared reflectance in camouflage studies. Greenler and O'Neil [4] discussed the heating of the human body by infrared radiation, particularly as it is affected by the clothing worn. Some observations on the effect of color on the absorption and transmission of radiation were reported by Rees and Ogden [12]. A paper along similar lines was presented by the Philadelphia Section of the A.A.T.C.C. [1]. Wright [17] presented an interesting qualitative analysis of the complexity of radiant energy penetration in materials such as textiles and granular substances. A discussion of infrared light in relation to blackout draperies and curtains was published by Millson [9]. Two National Bureau of Standards articles [2, 13] give information on the infrared transmission of plant and animal tissues, and on the ultraviolet transmission of fabrics. A review of the general subject of infrared production, transmission, reflectance, and measurement was given by Koller [8]. Standards and definitions of optical terms also have been surveyed [3].

Recently, Tuckerman [16] reviewed the history of the theory of reflection and transmission of light from a pile of plates. He noted the presence of incorrect formulas in some current texts and recent books. Also, he derived the formulas for a pile of absorbing plates by a method different from that used by Stokes [15], but he showed his solution, although different in form, to be equivalent to that of Stokes.

Theory

As beams of radiant energy pass through a textile (or other similarly subdivided materials), they are reflected from the surfaces of the fibers and are refracted by passing through individual fibers. A reflected beam, or one which has passed through and emerged from a fiber, may assume a path in any direction. The random path may be in the same direction as that of the entering beam, in the direction of the plane of the cloth, back in the direction of the light source, or in any angular position between these coordinates. Because the thickness of cloth generally is small in comparison to its lateral dimensions, it will be assumed that the amount of lateral scattering of light, compared with that which operates in a line perpendicular to the cloth, is small. This assumption—that is, that transmission and reflection are primarily in a direction perpendicular to the cloth—is made in this paper. The agreement between experimental points and the fitted curves shows that the formulas based on this assumption give satisfactory results over a wide range.

A fraction of the radiant beam is absorbed by the fibers of the cloth with each fiber surface reflection and with each passage through a fiber. If the cloth is not too thick, some of the incident light eventually finds its way through the tortuous path within the cloth and emerges as transmitted light. A part of the incident light which has entered the cloth will again find its way out of the cloth in the direction of the light source, and this is the reflected light. The amount of light con-

verted to thermal energy is the absorbed radiation. The problem of textile optics is to describe quantitatively the transmittance, reflectance, and absorptance of light, or radiant energy, by bulk textile fibers in terms of the number of fibers—that is, textile thickness, and the specific reflection and absorption characteristics of the fibers as arranged in the cloth.

Stokes [15, 16] has developed equations for the net transmittance, t_n, and the net reflectance, r_n, from a pile of parallel plates when each plate has an effective individual transmittance and reflectance, t and r, respectively. The analysis includes consideration only of the optical interaction between plates and does not deal with the relationships of t and r for individual plates with their basic optical constants. The Stokes equations for transmittance and reflectance of n plates are as follows:

$$t_n = \frac{c - c^{-1}}{cd^n - c^{-1}d^{-n}} \tag{1}$$

and

$$r_n = \frac{d^n - d^{-n}}{cd^n - c^{-1}d^{-n}}. \tag{2}$$

c and d are constants which are dependent only upon the transmittance and reflectance of the single plates of which the pile is composed.

The above equations may be applied to textile materials of different thicknesses, expressed as weight per unit area. Thus, t_w and r_w are the transmittance and reflectance of a material having a weight per unit area of w. For textiles, the constants c and d may be defined as follows:

$$c = \frac{1}{\alpha} \tag{3}$$

and

$$d = e^k, \tag{4}$$

leading to the following equations, after substitution in equations (1) and (2):

$$\left(\frac{I_t}{I_o}\right)_w = t_w = \frac{(1 - \alpha^2)e^{-kw}}{1 - \alpha^2 e^{-2kw}} \tag{5}$$

and

$$\left(\frac{I_r}{I_o}\right)_w = r_w = \frac{\alpha(1 - e^{-2kw})}{1 - \alpha^2 e^{-2kw}}. \tag{6}$$

The constant, α, is the reflectivity of the material when it is very (infinitely) thick. The constant, e^k, represents the fraction of energy that is lost by absorption alone in a unit weight per unit area of material. The extinction coefficient, k, will have reciprocal dimensions of those chosen for w—for example, k might be expressed in square meters per gram or in square yards per ounce.

It is interesting to observe the limits of equations (5) and (6). When the thickness of cloth, w, is zero, its transmittance, t_w, is 1.0. As $w \to \infty$, $t_w \to 0$. Also, when w is zero, the reflectance, r_w, is 0, and as $w \to \infty$, $r_w \to \alpha$. These limits are all those to be expected, and the last one also is in accord with equation (3).

For convenience in manipulation, equations (5) and (6) may be rearranged as follows:

$$\frac{I_o}{I_t} = \left(\frac{1}{1 - \alpha^2}\right) e^{kw} - \left(\frac{\alpha^2}{1 - \alpha^2}\right) e^{-kw} \tag{7}$$

and

$$\frac{I_o}{I_r} = \left(\frac{1}{1 - e^{-2kw}}\right) \alpha^{-1} - \left(\frac{e^{-2kw}}{1 - e^{-2kw}}\right) \alpha. \tag{8}$$

The absorptance of a fabric is defined as follows:

$$\left(\frac{I_a}{I_o}\right)_w = a_w = 1 - t_w - r_w. \tag{9}$$

Substitution of equations (5) and (6) in equation (9) gives the following final expression for absorptance:

$$\left(\frac{I_a}{I_o}\right)_w = a_w = \frac{(1 - \alpha e^{-kw})(1 - \alpha)(1 - e^{-kw})}{1 - \alpha^2 e^{-2kw}}. \tag{10}$$

It may be noted that when the material is very thick (that is, when $w \to \infty$), then the absorptance becomes:

$$\left(\frac{I_a}{I_o}\right)_w = 1 - \alpha. \tag{11}$$

Effect of Base Material Reflectance

When being dried, textiles may be subjected to radiant illumination from one side while the other side is backed up with a reflecting surface. Also, textiles frequently are supported by and are in contact with other surfaces, such as skin, other textiles, etc. The reflecting properties of the supporting surface greatly affect the optics of the fabric in contact with it. The following section gives a theoretical treatment from which, in principle, it is possible to compute the over-all absorptance, reflectance, and transmittance of a cloth-support system from a knowledge of the reflectance of the support and the constants, k and α, which are characteristic of the fabric and which, as will be shown later, may be evaluated by transmittance measurements.

Let the reflectance of the supporting surface be β, and let a perfect reflector have a value of $\beta = 1.0$. Because of the presence of the reflecting surface, multiple reflections must be considered. The diagram on page 77 represents a cloth and supporting surface and indicates, for any entering ray of $I_o = 1.0$, the relative values of the primary and succeeding multiple rays which leave the cloth by reflection and those which leave the system by transmission through the cloth and the support.

The rays transmitted through the system may be written as follows:

$$t_w(1-\beta), \quad t_w r_w \beta(1-\beta), \quad t_w r_w^2 \beta^2(1-\beta), \quad t_w r_w^3 \beta^3(1-\beta), \cdots. \tag{12}$$

The intensity of transmitted light by the system is given by the sum of this geometric series, as follows:

$$\left(\frac{I_t}{I_o}\right)_{\text{syst.}} = \frac{t_w(1-\beta)}{1-r_w\beta}. \tag{13}$$

The rays reflected by the fabric are:

$$r_w, \quad t_w^2\beta, \quad t_w^2 r_w \beta^2, \quad t_w^2 r_w^2 \beta^3, \cdots. \tag{14}$$

The intensity of light reflected by the system is given by the summation of the geometric series above, of which the first term is not a part:

$$\left(\frac{I_r}{I_o}\right)_{\text{syst.}} = r_w + \frac{t_w^2\beta}{1-r_w\beta}. \tag{15}$$

Through the use of equation (9) as well as of equations (13) and (15), the absorptance of the system may be computed to give the formula:

$$\left(\frac{I_a}{I_o}\right)_{\text{syst.}} = \frac{a_w(1+\beta(t_w-r_w))}{1-r_w\beta}. \tag{16}$$

The physical constants, k and α, for the fabric may be introduced into the above equations through substitutions for t_w, r_w, and a_w from equations (5), (6), and (10). The following terminal equations are obtained:

$$\left(\frac{I_t}{I_o}\right)_{\text{syst.}} = \frac{(1-\beta)(1-\alpha^2)e^{-kw}}{(1-\alpha^2e^{-2kw})\left(1-\dfrac{\beta\alpha(1-e^{-2kw})}{1-\alpha^2e^{-2kw}}\right)}, \tag{17}$$

$$\left(\frac{I_r}{I_o}\right)_{\text{syst.}} = \frac{\alpha(1-e^{-2kw})}{1-\alpha^2e^{-2kw}} + \frac{\beta(1-\alpha^2)^2e^{-2kw}}{(1-\alpha^2e^{-2kw})^2\left(1-\dfrac{\beta\alpha(1-e^{-2kw})}{1-\alpha^2e^{-2kw}}\right)}, \tag{18}$$

$$\left(\frac{I_a}{I_o}\right)_{\text{syst.}} = \frac{(1-\alpha e^{-kw})(1-\alpha)(1-e^{-kw})\left|1+\beta\left(\dfrac{(1-\alpha^2)e^{-kw}-\alpha(1-e^{-2kw})}{1-\alpha^2e^{-2kw}}\right)\right|}{(1-\alpha^2e^{-2kw})\left(1-\dfrac{\beta\alpha(1-e^{-2kw})}{1-\alpha^2e^{-2kw}}\right)}. \tag{19}$$

If the reflectance, β, of the supporting surface is zero, then equations (17), (18), and (19) necessarily simplify to their counterparts when the fabric alone is being subjected to radiant energy (that is, to equations (5), (6), and (10)).

The above equations are not restricted to infrared radiation, but are, ideally, those for monochromatic radiation.

Experimental Procedure

Apparatus

To measure the transmission of infrared radiation through piles of textiles, an optical train was used consisting of an R-40 drying lamp, a series of round apertures, a long collimator tube, the textile pile, and an infrared detector. Figure 1 presents a diagram of the apparatus. The entire apparatus was mounted vertically with the infrared source at the top. The R-40 drying lamp was installed in an enclosed black metal cylinder which was water-cooled. The constancy of radiant output was assured through manual control of the voltage by means of a variable transformer. The intensity of the radiation to the cloth was capable of a variation from 0.001 to 4.015 milliwatts per square centimeter through the use of round apertures of different sizes in slide diaphragms which were placed horizontally in a slot beneath the lamp. A long tube was provided to conduct the light into the measuring unit which was placed in a conditioned chamber. The tube, which was 1.4 meters long and 7 centimeters in internal diameter, was used as a collimator to assure an approximately parallel and uniform beam of light. The measurement of infrared energy was accomplished by the use of a thallium sulfide photoconductance cell obtained through the courtesy of the Princeton Research Laboratories of the Radio Corporation of America.

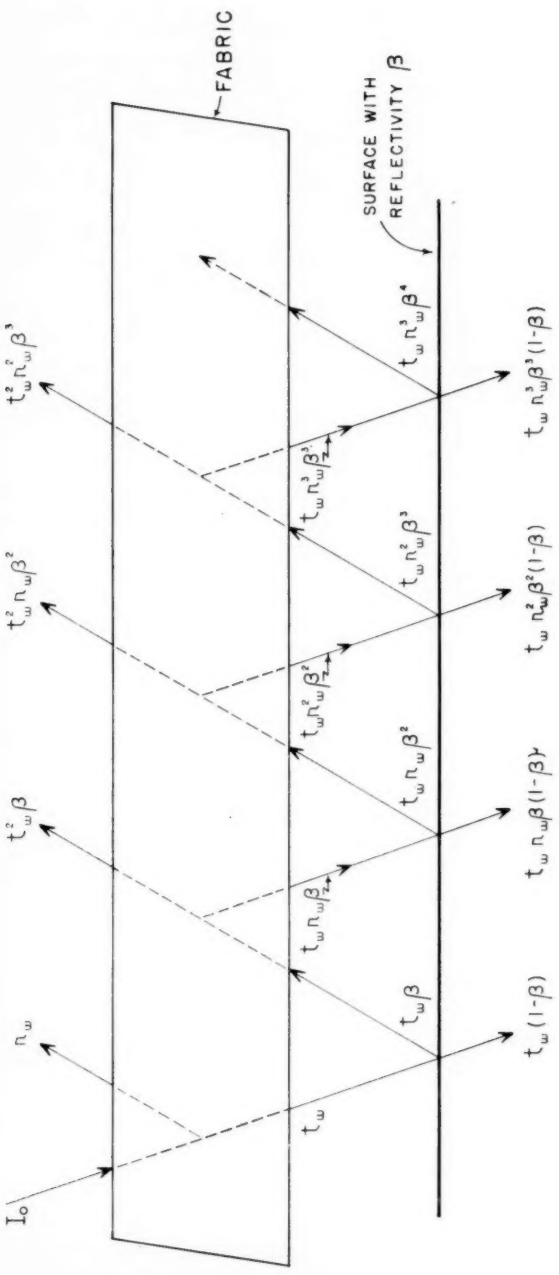

Figure 2 shows the effective wave length-versus-sensitivity characteristics of a thallium sulfide cell and an R-40 drying lamp. The spectral response curve for the thallium sulfide cell was measured by Hippel, Chesley, Denmark, Ulin, and Rittner [6]. Also, there are shown in the figure the combined characteristics of the R-40 lamp and the thallium sulfide cell. The resulting curve has a moderately sharp peak at 9,700 Ångstrom units. For comparison, the wave length-intensity curve for average noon sunlight on a clear day also is given.

The thallium sulfide cell, which resembles a radio tube in shape, has the property of changing its resistance when illuminated. It was contained in the cell housing inside the conditioning chamber. The cell housing was capable of being moved vertically on the rods to which it was fixed. A removable sample carrier consisting of two brass plates, centered by means of brass pins, was fitted to the top of the cell housing. These plates were each provided with a hole, measuring 5.5 by 9.0 centimeters, directly above a similar hole in the cell housing, thus exposing the cell directly under the cloth. The textile fabric, or pile of fabrics, was placed over the hole on the bottom plate of the holder and the top plate was placed over it. The pile was held in position by the weight of the top plate, which in turn was prevented by the brass pins from moving laterally. Glass could not be used for the carrier because it is opaque to some of the infrared radiation.

The constant humidity and temperature chamber consisted of a double-walled, insulated wooden box about 22 inches on each side, with a door at the front. The door was fitted with a double-pane glass window, the dead air space between the panes serving as insulation. The door also was provided with two armholes equipped with long-sleeved, thin, rubber gloves, the ends of which were fastened tightly around the armholes. By placing his hands in these gloves, the operator could manipulate samples inside the chamber without appreciably affecting the conditions therein. A small centrifugal blower was used within

the chamber to provide air circulation. The temperature was regulated by a mercury-in-glass electric temperature controller, which operated a relay for switching off and on two light bulbs which served as heaters. Throughout the study, the temperature was maintained at 33.7°C. The humidity was controlled by means of saturated salt solutions of various types [7]. The tray containing the salt solution was placed beneath the false bottom of the chamber and part of the air stream from the blower was diverted over it. The humidity was measured by means of a wet and dry bulb psychrometer placed in the direct air stream from the blower.

Materials

The materials studied included viscose rayon, cellulose acetate rayon, cotton, woolens, and worsteds. In all the samples except the cotton, a variety of sample weights was used for each material. The weave and weight characteristics of all samples are presented in Table I. All samples were plain weave and without finish. The fabric weights listed are dry weights obtained by the A.S.T.M. oven-drying procedure.

Operations

Calibration. The measuring equipment for the thallium sulfide cell was located outside the chamber and connections were made with flexible leads. The circuit consisted of No. 6 dry-cell batteries in series-parallel, producing about 4.8 volts, a 0.06-megohm carbon resistor, and the thallium sulfide cell. Since the maximum current in the circuit was about 5 microamperes, the carbon resistor did not change its resistance and the batteries did not deteriorate appreciably. A calibrated electronic voltmeter was employed to read the voltage drop across the resistor. The voltage was directly proportional to the current in the circuit, and the current indicated the intensity of the light. Because the characteristics of the thallium sulfide cell are non-linear, a calibration curve was prepared, and from this the intensity of the light could be read.

The elements used in preparing the calibration curve of the thallium sulfide cell were a series of apertures, an RCA type 922 high-vacuum phototube which has a linear response over the range employed here, and an eight-junction bismuth-silver calibrated Eppley thermopile, No. 1038, with a sensitivity of 0.1301 microvolt per microwatt per square centimeter. The latter cell permitted the results to be placed upon an absolute basis.

The linear-response vacuum phototube was first placed upon an absolute basis by comparison with the thermopile, each unit in turn being placed at the measuring position at the end of the collimator tube. Comparison of the two instruments was possible in an overlapping range of light intensity. The now-calibrated photocell was used, in turn, to calibrate the series of apertures of different sizes in such a way that the radiant intensity at the measuring station was known with any aperture in position. With this information, it was finally possible to calibrate the thallium sulfide cell in terms of radiant flux versus voltage drop across the 0.06-megohm resistor. Figure 3 presents the calibration curve. The choice of a semi-logarithmic scale for this calibration plot is entirely for convenience and has no theoretical justification.

Measurements. Samples of textiles to be studied, cut to fit the sample carrier (8 × 12 cm.), were placed in the chamber. They were hung on lines within the chamber to permit air circulation and

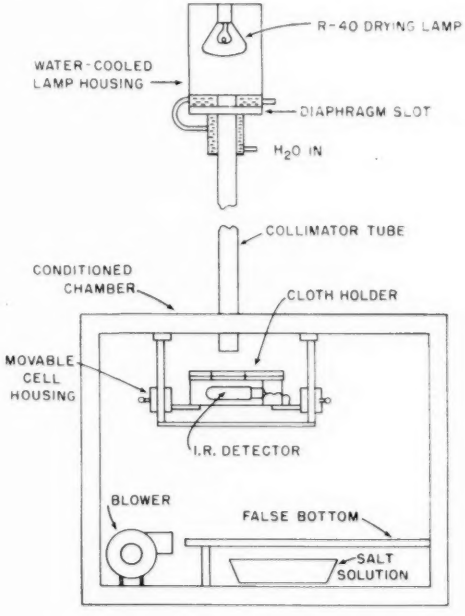

FIG. 1. *Diagram of optical train for infrared transmittance measurements.*

TABLE I. CHARACTERISTICS OF TEXTILE MATERIALS USED

NOTE: All samples are plain weave. All samples, unless noted in Table II or on graphs, are without finish. All weights of fabric are oven-dry weights.

Material	Sample No.	Picks per 10 cm.	Weight of fabric (gm./sq. m.)
Viscose Rayon			
Warp: 166.7 grex, 40 filament, continuous filament 456.7 ends/10 cm.			
Filling: 166.7 grex, 40 filament, continuous filament	F-2	228.5	108
	F-3	181.2	98
	F-4	130.0	97
	F-5	78.8	87
Filling: 164.3 grex, rayon staple	S-2	228.5	107
	S-3	181.2	99
	S-4	130.0	92
	S-5	78.8	79
Cellulose Acetate Rayon			
Warp: 83.4 grex, 20 filament, continuous filament Twist: 102.4 turns/10 cm. 315 ends/10 cm.			
Filling: 83.4 grex, 20 filament, continuous filament Twist: 102.4 turns/10 cm.	A-1	157.6	40
	A-2	236.3	48
	A-3	315.0	54
	A-4	362.3	60
Cotton			
Warp: Approximately 180 grex 270 ends/10 cm.			
Filling: Approximately 180 grex	C-1	210.0	82
Woolens			
Warp: 769 grex Twist: 65 right/10 cm. and 65 left/10 cm. alternately 147.7 ends/10 cm.			
Filling: 555 grex Twist: 65 left/10 cm.	O-1	150	206
	O-3	130	207
	O-4	120	204
	O-5	110	203
Filling: 909 grex Twist: 50 right/10 cm.	O-16	120	257
	O-18	100	234
	O-20	80	233
Worsteds			
Warp: Alternating 1:1 384.6 grex and 312.3 grex Twist: 86 right/10 cm. Twist: 100 right/10 cm. 244.2 ends/10 cm.			
Filling: 263 grex Twist: 115 right/10 cm.	R-1	170	160
	R-3	150	154
	R-4	140	155
	R-5	130	161
Filling: 312.3 grex Twist: 100 right/10 cm.	R-9	130	163
Filling: 454 grex Twist: 84 right/10 cm.	R-16	130	199
	R-18	110	181
	R-20	90	186

Conversion Factors:

Ends/10 cm. or picks/10 cm. × 0.254 = ends/inch or picks/inch

Grex = grams per 10,000 meters

(grex) (0.9000) = denier

1/(grex) (1.693) = cotton count; (hanks/pound, hank is 840 yards)

1/(grex) (1.128) = wool count; (hanks/pound, hank is 560 yards)

(grams/square meter) × 0.0322 = ounces/square yard

rapid conditioning. The desired number of samples were then placed in the holder, the holder was brought to the end of the collimator tube, and transmission measurements were made.

Experimental measurements consisted of values for a "dark voltage" and a "reading voltage." The "dark voltage" represents the resistance of the cell when no light is striking it. (The cell does not have an infinite dark-resistance as with the photoemission type.) The "reading voltage" represents the resistance of the cell for the intensity of light existing at the time. The difference in resistances or voltages thus measured represents the net intensity of light. Measured voltages were in each instance corrected for the calibration error of the electronic voltmeter. The radiation intensity was then read from the cell calibration curve. The aperture used in the experiment being known, the intensity of light incident on the textile was likewise known. Dividing the transmitted intensity by the incident gave the transmittance. Accuracy and precision were limited primarily by the electronic voltmeter, the thallium sulfide cell, and the illumination source. The voltmeter always was turned on for about an hour prior to use and was frequently calibrated against a General Electric standard voltmeter. With these precautions, an accuracy of perhaps 1 percent of the scale reading was obtained. The thallium sulfide cell exhibited a slight tendency to drift under constant illumination. However, a constant period free of drift, after about 30 seconds of illumination, was ob-

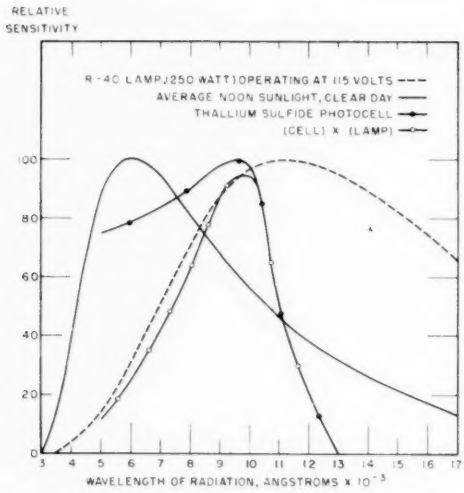

FIG. 2. *Relative sensitivity versus wave length of R-40 lamp, thallium sulfide cell, and lamp-cell combination. Also sunlight for comparison.*

served. Readings were taken during this period. The voltage applied to the R-40 drying lamp was quite critical, since it affected not only the intensity but also the color temperature of the radiation. Errors from this source were minimized by manual adjustment of the voltage of the lamp.

Since the thickness of the fabric pile was varied quite widely, the intensities of light impinging on the thallium sulfide cell also varied over a great range. The range of transmitted intensities was larger than the range of the cell, and therefore the slide diaphragms were used to vary the intensity of incident radiation. This technique, however, introduced into the results whatever error there might have been in the original calibration of the apertures. In order to determine this error, a fabric pile was placed in the apparatus and its percent transmission was measured. This operation was performed several times, varying the intensity of incident light by means of the apertures but keeping the intensities within the measuring range of the thallium sulfide cell. The transmittance should, of course, remain constant, and, should it vary, its variation would be a measure of the errors involved. It was found in a number of experiments that the average deviation of the transmittance between orifices was 3.1 percent.

The following is a sample calculation for Figure 15. The material was Worsted Sample R-9, dyed with wool black dye. One layer was used for which the oven-dry weight was 163.3 grams per square meter and the moisture regain was 10.2 percent. The transmission data are as follows:

	Dark reading (volts)	Reading (volts)
Voltage readings	1.160	2.440
Corrections for voltmeter	−0.072	−0.108
Corrected readings	1.088	2.332

The difference between the two readings represents the actual intensity of light passing through the textile; the dark reading is subtracted from the reading:

$$2.332 - 1.088 = 1.244 \text{ differential voltage.}$$

The intensity of transmitted radiation may be read from Figure 3 to be 0.077 milliwatt per square centimeter. Aperture No. 3 was used. From its calibration, it was known to permit an approach intensity of 0.4785 milliwatt per square centimeter. The transmittance, therefore, is computed by division:

$$0.077 / 0.4785 = 0.161.$$

Experimental Results

The experimental variables were: the type of fiber of which the fabric was made, the structure of the fabric, its moisture content, and dyeing. Experiments were performed for each condition by measuring the transmission of successive layers of fabrics, piled one on another, until the limit of sensitivity of the thallium sulfide cell was reached. In some cases, transmission measurements were made to values as low as 0.0002 fraction transmissivity. Experimental results are presented in Table II and in Figures 4 through 16. The graphs relate fraction transmission and thickness of fabric pile, expressed as grams per square meter (dry basis). A semi-logarithmic presentation of the data was chosen because of the exponentials in the equations for transmissivity and because, at the same time, data covering transmission over as many as four orders of magnitude may be conveniently presented in a single graph.

Through the use of equation (7), the characteristic constants, k, the extinction coefficient, and α, the limiting reflectivity, were computed from the experimental data for the various conditions of

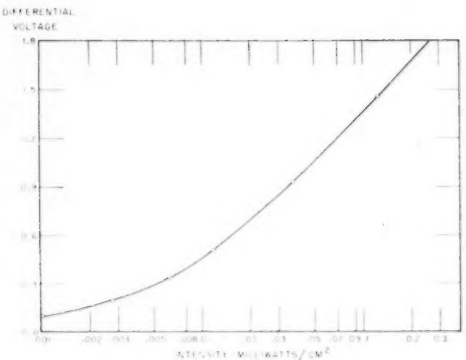

FIG. 3. *Calibration curve of thallium sulfide photoconductance cell.*

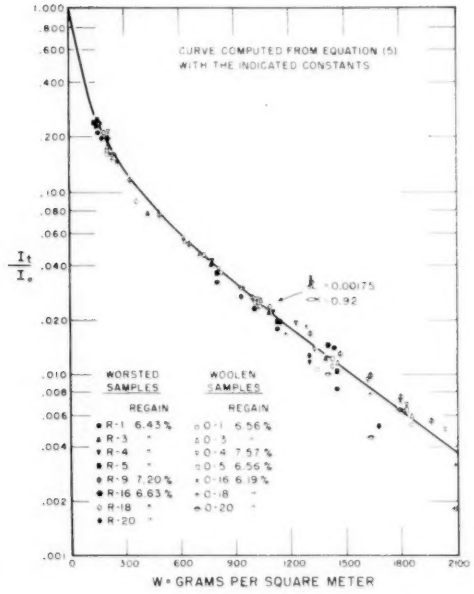

FIG. 4. *Composite transmittance curve for woolen and worsted fabrics.*

operation. Because of the nature of equation (7), trial-and-error determination of the best fit with the data was necessary. In Figures 4 through 16, the actual experimental points are indicated by dots, dashes, squares, etc., and the line drawn through them was computed from transmittance equation (5) using the best values for k and α.

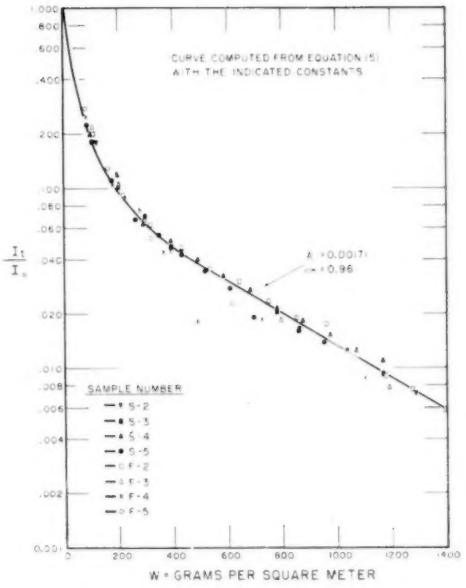

FIG. 5. *Composite transmittance curve for viscose rayon fabrics.*

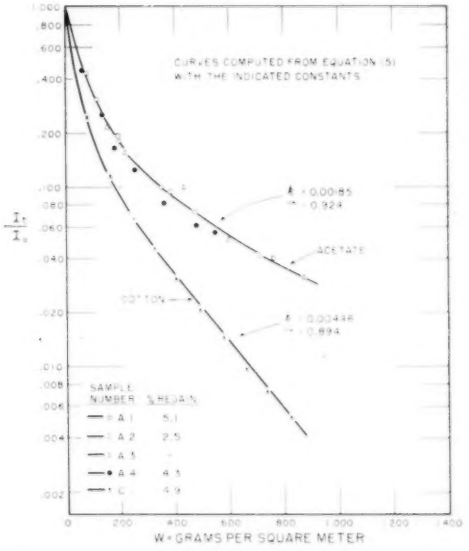

FIG. 6. *Composite transmittance curve for cellulose acetate rayon fabrics and transmittance curve for cotton fabric.*

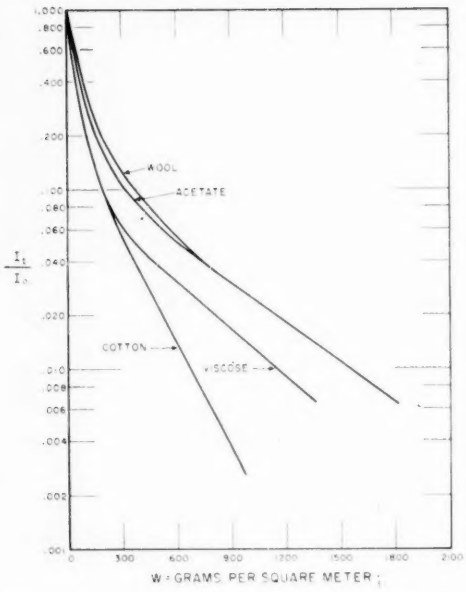

FIG. 7. *Comparison of transmittance curves for wool, acetate rayon, viscose rayon, and cotton fabrics.*

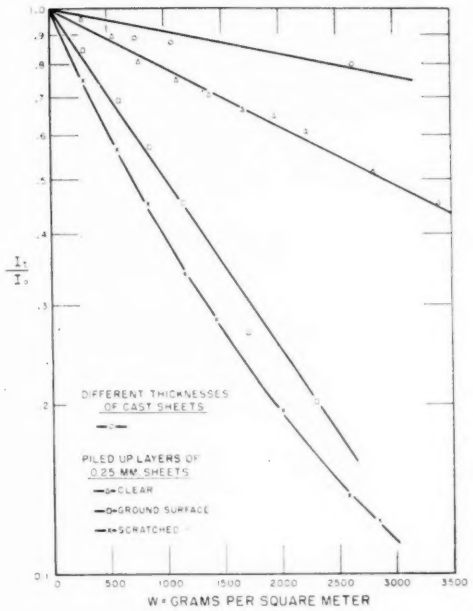

FIG. 8. *Transmittance curves for clear sheet cellulose acetate and for scratched and ground sheets of this material.*

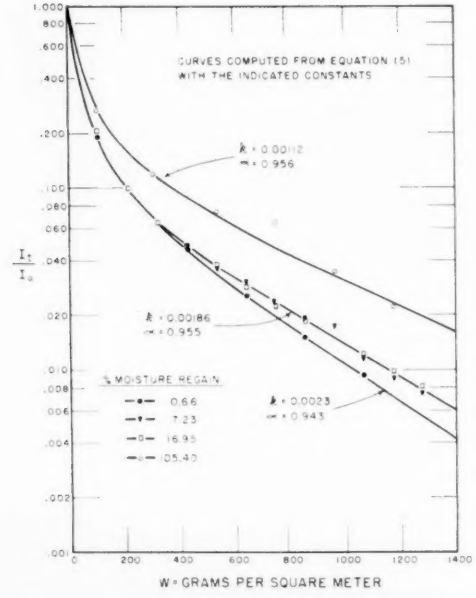

FIG. 9. *Transmittance curves for a viscose rayon fabric at different moisture contents.*

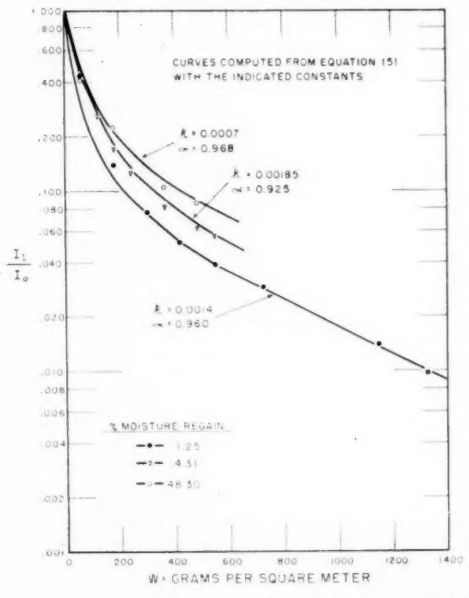

FIG. 10. *Transmittance curves for an acetate rayon fabric at different moisture contents.*

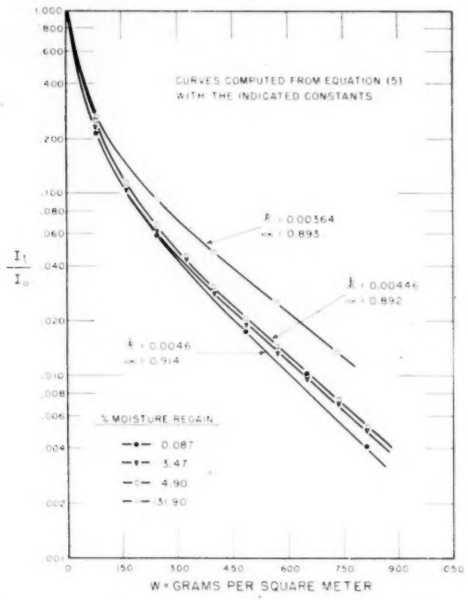

FIG. 11. *Transmittance curves for a cotton fabric at different moisture contents.*

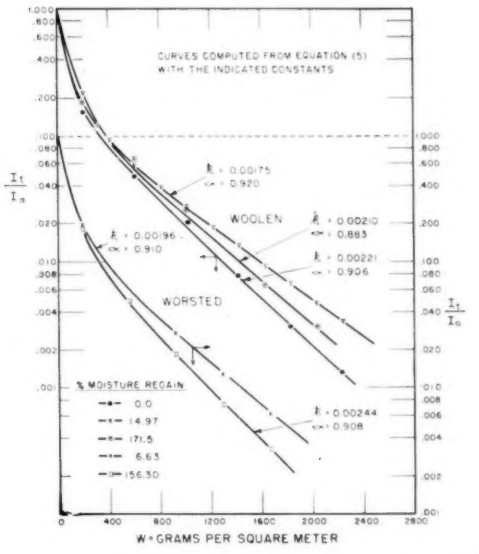

FIG. 12. *Transmittance curves for woolen and worsted fabrics at different moisture contents.*

The closeness with which the equation describes the data is noteworthy and is strong evidence that the model chosen in developing the equation is a satisfactory one.

Discussion

Type of Fiber and Weight and Structure of Fabric

The effect of type of fiber, weight, and structure of weave on the transmission curve is represented in Figures 4, 5, and 6. In Figure 4, the interesting result is evident that all data for woolen and worsted samples fall satisfactorily upon a single curve. The moisture content was between 6.2 and 7.6 percent regain. As noted in Table I, the weaves varied considerably and the weights of single fabrics ranged from 154 to 257 grams per square meter. The conclusion reached is that within this range the construction of the textile does not constitute a major variable. The picks per inch, number of ends, weight of yarns, and, probably, weave do not affect the transmittance markedly, except in so far as they affect the weight of material. The important variable affecting transmittance is the weight of material per unit area—that is, the number of fibers in the direction of the path of illumination. Similar conclusions are reached for viscose rayon and acetate rayon as shown in Figures 5 and 6.

A comparison between fabrics of different fibers is given in Figure 7, which presents average transmittance curves for materials made of wool, acetate rayon, viscose rayon, and cotton. It is apparent that the structure of the fibers of which the fabrics are composed affects the transmittance, that the characteristic curves for wool and acetate rayon are quite close to each other, and that the curve for viscose rayon exhibits somewhat smaller values for transmittance for a given weight of material. The fibers of these materials all are approximately round and are of the same order of size—approximately 0.02 mm. The transmittance curve for cotton exhibits a markedly different slope and considerably decreased values for transmittance. The cotton fiber has a flattened cross section and is twisted down its length. These physical characteristics make the fiber more diffusing to light, which may account for the greater decrease in transmittance for cotton per unit thickness than for the other materials studied.

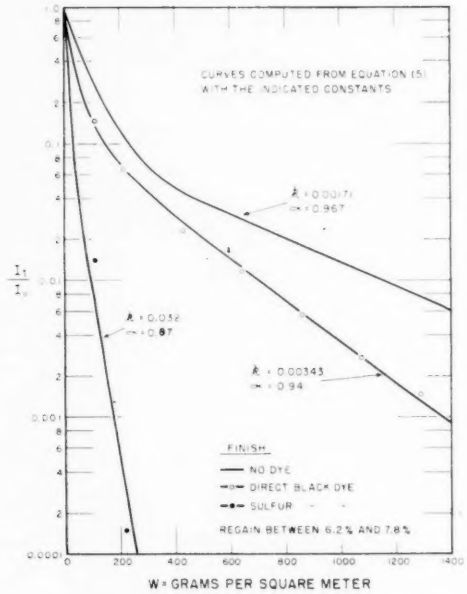

FIG. 13. *Transmittance curves for undyed viscose rayon fabric compared with curves for two dyed specimens.*

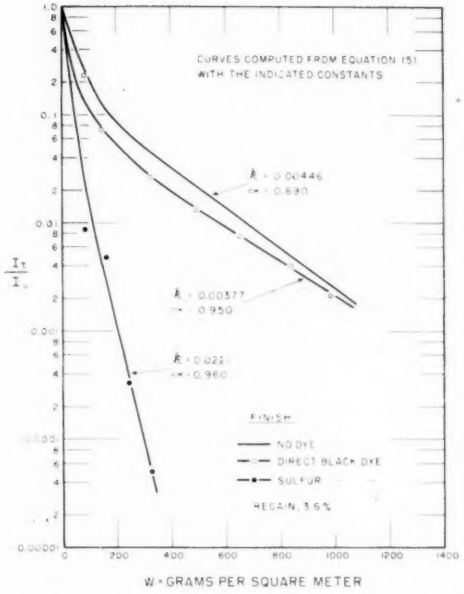

FIG. 14. *Transmittance curves for an undyed cotton fabric compared with curves for two dyed samples.*

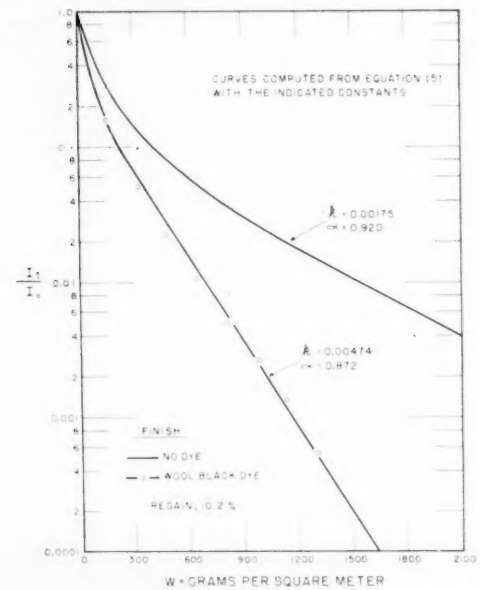

FIG. 15. *Transmittance curves for a dyed and undyed worsted fabric.*

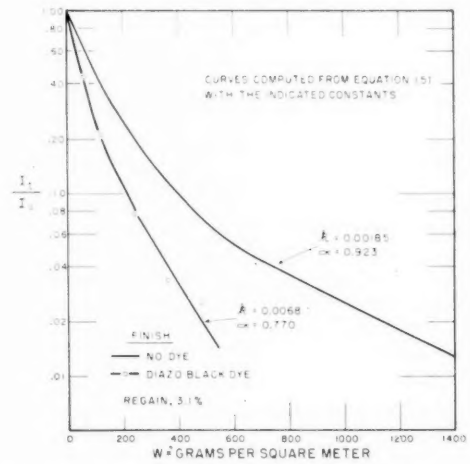

FIG. 16. *Transmittance curves for a dyed and undyed fabric of cellulose acetate rayon.*

TABLE II. EXTINCTION COEFFICIENT, k, AND REFLECTION COEFFICIENT, α, COMPUTED FROM EXPERIMENTAL TRANSMISSION MEASUREMENTS THROUGH PILES OF TEXTILE MATERIALS

Material	Figure No.	Condition	k	α
EFFECT OF FIBER SUBSTANCE AND WEIGHT OF WEAVE				
Woolen and Worsted	4	Regain from 6.2 to 7.6%	0.00175	0.920
15 different weights				
Viscose Rayon	5	Regain from 6.2 to 7.8%	0.00171	0.960
8 different weights, staple and continuous filament				
Acetate Rayon	6	Regain from 2.5 to 5.1%	0.00185	0.924
4 different weights				
Cotton	6	Regain 4.9%	0.00446	0.894
1 weight				
EFFECT OF MOISTURE				
Viscose Rayon	9	Regain 0.7%	0.00230	0.943
		7.2	0.00186	0.955
Sample S-2		17.0	0.00186	0.955
		105.0	0.00112	0.956
Acetate Rayon	10	Regain 1.3%	0.00140	0.960
		4.3	0.00185	0.925
Sample A-4		48.3	0.00070	0.968
Cotton	11	Regain 0.1%	0.00460	0.914
		3.5	0.00446	0.892
Sample C-1		4.9	0.00446	0.892
		131.9	0.00364	0.893
Woolen and Worsted				
Woolen Sample O-4	12	Regain 0.0%	0.00221	0.906
		14.9	0.00175	0.920
		171.5	0.00210	0.883
Worsted Sample R-20	12	Regain 6.6%	0.00196	0.910
		156.3	0.00244	0.908
EFFECT OF DYES				
Viscose Rayon	13	Regain from 6.2 to 7.8%		
Sample F-2		No dye	0.00171	0.967
		Calcomine Black G, 200%	0.00343	0.940
		Calcogene Black RBCF (Sulfur)	0.0320	0.867
Cotton	14	Regain 3.6%		
Sample C-1		No dye	0.00446	0.890
		Calcomine Black G, 200%	0.00377	0.950
		Calcogene Black RBCF (Sulfur)	0.0221	0.960
Worsted	15	Regain 10.2%		
Sample R-9		No dye	0.00175	0.920
		Wool Black 4B (Kahlbaum)	0.00474	0.872
Acetate Rayon	16	Regain 3.1%		
Sample A-4		No dye	0.00185	0.923
		Diazo Black	0.0068	0.770

A comparison was made between the transmission for sheet material and for textile fibers. Transmission measurements were made on sheet cellulose acetate cast from the material ordinarily used for the spinning of fibers. Figure 8 shows an almost linear relationship between the logarithm of the fraction transmission and the thickness of layer for clear films, Beer's law being satisfactorily approximated. The surfaces of these sheets were then ground or scratched and the transmission measurements were repeated. It was found that the transmittance was greatly decreased, and the curvilinear nature of the results, characteristic for low transmittance, also is observable with the scratched sheets. It is evident that the subdivided nature of the textile fabrics is responsible for the type of transmittance curves obtained. In comparing the transmittance of these materials with that of acetate rayon in Figure 6, the difference in transmittance scale should be noted.

Moisture Content

Experiments were performed with samples of viscose rayon, acetate rayon, cotton, woolen, and worsted materials to determine the effect of moisture content on infrared transmittance. In each case, samples of the material were brought to equilibrium at different regains by means of humidity control or drying and the normal transmittance

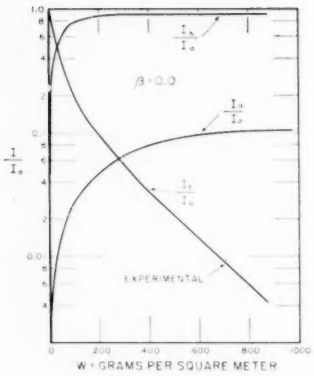

FIG. 17. *Measured transmittance curve and computed reflectance and absorptance curves for cotton. Reflectivity, β, of supporting surface is 0.*

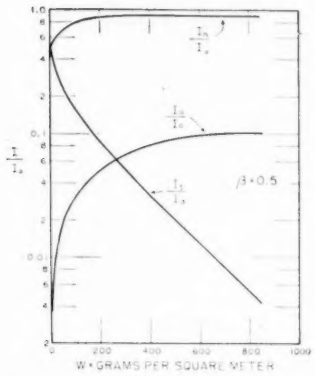

FIG. 18. *Computed transmittance, reflectance, and absorptance curves for cotton. Reflectivity, β, of supporting surface is 0.5.*

curves for different layers of the material were determined. In each instance, for one set of experiments a very high moisture content was also provided by moistening and centrifuging the samples. The results are presented in Figures 9–12. At low values of regain (below 100 percent), the remarkable result was found that the transmittance increased with increasing moisture content. Because water is a good absorber of infrared energy in the radiation wave length range employed, it would be anticipated that increasing moisture content would decrease the transmittance. A possible explanation of this apparent anomaly is that the water is absorbed by the fibers, causing them to swell, and that the optical properties of the fibers are altered, leading to an increase in the effective transmittance. Such an effect would not be expected to be carried on indefinitely as increasing amounts of moisture are added, for ultimately, as excess unabsorbed water is accumulated, the transmittance of infrared energy with increasing moisture content must again be expected to decrease. In the case of viscose, acetate, and cotton samples, this turning point was not reached at the higher moisture contents, but in both the woolen and the worsted samples it is observed that the maximum of transmittance with moisture content was exceeded at the largest regains.

Dyeing

The effect of dyes on infrared transmission was marked (see Figures 13–16). Only black dyes were used. Cotton and viscose rayon were dyed with direct black and with sulfur black dyes. The former dye is known to produce a high degree of reflectance, whereas the latter produces a low infrared reflectance [9]. Direct black dye reduced the infrared transmission compared to that of undyed samples only moderately, but sulfur black reduced the transmission spectacularly. The marked effect of wool black dye on worsted samples and of a diazo black dye on cellulose acetate are also demonstrated in Figures 15 and 16. The specific dyes are identified in Table II and the effect of dye on values for k and α compared to that for an undyed sample is also shown in that table. In each instance, the extinction coefficient was increased by the dyeing process. With the exception of the cotton sample, the reflectivity, α, was found to be decreased by dyeing, the greatest effect being with sulfur black dyes, which most strongly absorb infrared radiation.

Effect of Base Material Reflectance

Equations (17), (18), and (19) have been derived for the over-all transmittance, reflectance, and absorptance of a fabric pile having the characteristic constants α and k, and supported by a surface of reflectance, β. Although no direct measurements have been made upon such a system, it is interesting to explore the possible effect of the magnitude of β upon each of the optical properties of the system as computed by these equations For this purpose, cotton is chosen for an illustra-

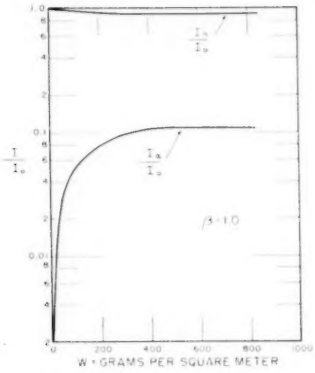

FIG. 19. *Computed reflectance and absorptance curves for cotton. Reflectivity, β, of supporting surface is 1.0.*

tion. From transmittance measurements the fabric constants at a moisture content of 4.9 percent were evaluated to be $k = 0.00446$ and $\alpha = 0.892$. For this material the over-all transmittance, reflectance, and absorptance have been computed for supporting surface reflectivities of 0, 0.5, and 1.0. The results of these computations are presented in Figures 17–19.

In Figure 17, with zero reflectance for the supporting surface, the transmittance curve is in close agreement with the experimental values for cotton, as shown previously. The computed reflectance rises sharply from a value of zero as increasing thicknesses of fabric are considered, and soon levels off and approaches a limiting value of 0.892 at infinite thickness. The computed absorptance also rises with increasing fabric thickness from an initial value of zero to an ultimate value of about 10 percent with very thick samples.

When the supporting surface is completely reflecting (Figure 19), the effective transmittance of the cloth-support system is zero and hence no transmittance curve appears. When no cloth is present, the reflectance of the support alone is 1.0, and as cloth is added in layers the reflectance decreases and ultimately reaches the same limiting value of 0.892. The absorptance increases as in the previous case and reaches a slightly higher ultimate limit.

An intermediate condition, when $\beta = 0.5$, is presented in Figure 18. The initial reflectivity and transmissivity of the support surface each has a value of 0.5, and the system reflectance and transmittance curves start at this value and develop in a manner intermediate between the curves for the two previous cases.

NOMENCLATURE

a_w = absorptivity of textile, $a = I_a/I_o$, having thickness, w g./m.^{2}, dimensionless
c = a constant in Stokes' equation, dimensionless
d = a constant in Stokes' equation, dimensionless
e = base of Naperian logarithms
I = intensity of radiant energy perpendicular to fabric, milliwatts/m.^{2}
I_a = amount of energy absorbed per unit time and and area when fabric thickness is w, milliwatts/m.^{2}
I_o = intensity of energy approaching fabric, milliwatts/m.^{2}
I_r = amount of energy reflected per unit time and area when fabric thickness is w, milliwatts/m.^{2}
I_t = amount of energy transmitted per unit time and area when fabric thickness is w, milliwatts/m.^{2}
k = extinction coefficient, (g./m.^{2})$^{-1}$
n = number of layers of absorbing-reflecting planes in Stokes' equation
r_n = reflectivity, $r_n = (I_r/I_o)_n$, for n parallel plates, dimensionless
r_w = reflectivity, $r_w = (I_r/I_o)_w$, for fabric thickness, w, dimensionless
t_n = transmissivity, $t_n = (I_t/I_o)_n$, for n parallel plates, dimensionless
t_w = transmissivity, $t_w = (I_t/I_o)_w$, for fabric thickness, w, dimensionless
w = fabric thickness, g./m.^{2}
α = limiting reflectivity when w is infinite
β = reflectivity of supporting surface adjacent to fabric and on side opposite to radiation source

Acknowledgments

The authors wish to acknowledge their indebtedness to Prof. John Tukey of the Princeton University Mathematics Department for advice and suggestions regarding the mathematical treatment of the data. The thallium sulfide photoconductance cell, essential to this study, was made available by the Princeton Research Laboratories of the Radio Corporation of America through Mr. E. Engstrom and Dr. G. Morton.

The authors are greatly indebted also to the following persons and companies for providing materials and services: Dr. F. Bonnet, American Viscose Corporation, for especially woven samples of viscose rayon; Dr. W. von Bergen and Mr. C. S. Clutz, Forstmann Woolen Company, for especially woven woolen and worsted samples; Mr. R. L. Churchill, Tennessee Eastman Corporation, for samples of clear, unplasticized yarn-type cellulose acetate in sheet form; Mr. G. H. Hotte, A. M. Tenney Associates, Inc., for especially woven cellulose acetate rayon; Mr. K. H. Klipstein and Dr. A. L. Peiker, Calco Chemical Division of American Cyanamid Company, for dyeing certain fabrics.

Literature Cited

1. A.A.T.C.C., Philadelphia Section, *Am. Dyestuff Reptr.* **36**, P159 (1947).
2. Coblentz, W. W., Stair, R., and Schoffstall, C. W., *J. Research Natl. Bur. Standards*, Aug., 1928.
3. Committee on Colorimetry, *J. Opt. Soc. Am.* **34**, 183 (1944).
4. Greenler, H. F., and G'Neil, F. J., TEXTILE RESEARCH JOURNAL **17**, 63 (1947).
5. Gregory, J., *J. Text. Inst.* **21**, T57 (1930).
6. Hippel, Chesley, Denmark, Ulin, and Rittner *J. Chem. Phys.* **14**, 355 (1946).
7. "International Critical Tables," 1st Ed., New York, McGraw-Hill Book Co., 1926, Vol. 1, p. 67.
8. Koller, L. R., *General Electric Rev.* **44**, 167 (1941).
9. Millson, H. E., *Calco Tech. Bull.*, No. 618, Calco Chem. Div., Am. Cyanamid Co., Bound Brook, N. J.
10. Paul, G. T., and Wilhelm, R. H., TEXTILE RESEARCH JOURNAL **18**, 573 (Oct. 1948).
11. Preston, J. M., and Tsien, P. C., *J. Soc. Dyers and Colourists* **62**, 242 (1946).
12. Rees, W. H., and Ogden, L. W., *J. Text. Inst.* **37**, T113 (1946).
13. Stair, R., and Coblentz, W. W., *J. Research Natl. Bur. Standards* **15**, Sept. 1935.
14. Stearns, E., *Am. Dyestuff Reptr.* **33**, 131 (1944).
15. Stokes, G. G., *Phil. Mag.* (4) **24**, 480 (1862); *Proc. Roy. Soc., London* **11**, 545 (1862).
16. Tuckerman, L. B., *J. Opt. Soc. Am.* **37**, 818 (1947).
17. Wright, W. D., "The Measurement of Colour," London, A. Hilger, 1944, pp. 8–25.

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A Strain-Gage System for Fiber Testing

S. Leonard Dart and L. E. Peterson

Chemical Research Department, American Viscose Corporation, Marcus Hook, Pennsylvania

Abstract

A precision research instrument for the measurement of stress-strain-time properties of textile materials, which was constructed in the research laboratory of the American Viscose Corporation, is described. Classification of this instrument as a research tool rather than as a routine testing instrument allows more flexibility in operating conditions. It is of the constant-rate-of-extension type, for use on all textile materials from single filaments to fabrics. The instrument consists essentially of a constant speed drive, a Statham gage, and a Brown recording potentiometer.

A PRECISION RESEARCH INSTRUMENT for measuring stress-strain properties of textile materials at constant rate of extension and with a sufficiently wide force range to test single filaments, yarns, cords, and fabrics was desired by this laboratory. The instrument was also required to meet certain definite specifications which are dictated by fiber properties. In view of the fast rate of stress relaxation of many materials, any instrument which involves mechanical balancing of forces should be used with an accuracy which it is almost impossible to attain, since the force indicated after any mechanical motion depends not only upon the end-point but also upon the manner in which this point is reached. For instance, if the tension in a stretched fiber is to be measured by attaching the fiber to one side of a beam balance, with a weight added to the other side to balance, the weight which must be added will depend to a great extent upon how it is added and whether or not there is mechanical oscillation. For highly elastic materials such as rubber, this effect is of little consequence, but for most textile materials it is of great importance. An ideal mechanism would be one in which the force-measuring device involved a minimum of mechanical oscillation, motion, and inertia.

The instruments commercially available were unsatisfactory; therefore it seemed advisable to design and build a new instrument.

The Instrument

The instrument which is described here is the best approach to the ideal conditions which could be found. The mechanical motion and inertia of the force-indicating mechanism are very small, there are no mechanical oscillations involved, and all the balancing motions are electrical, not mechanical. This instrument is a combination of the Statham gage and the Brown strip-chart Electronik recording potentiometer. The Statham gage is an unbonded electric strain gage which combines small mechanical motion (0.0015 inch maximum) with high voltage output. This output is strictly linear with load and is sufficient to be put directly into the recorder without any additional amplification. The gage in itself has a definite maximum load, but this can be extended almost indefinitely by using it to measure the displacement of dynamometer rings.

The recorder used was the standard 0-10 mv. high-speed Electronik recording potentiometer. Its strip chart has an 11-inch calibrated width which is handy to use in conjunction with ordinary graph paper. The recorder has been modified somewhat to facilitate its use. The chart drive has been made reversible and the chart speed range has been extended to include 4 in. min. and $\frac{1}{4}$ in. min. The potentiometer circuit was modified in order to make the range of the instrument continuously variable down to less than 1 mv. A zero adjustment was also inserted in order that the zero position could be put anywhere on the scale.*

* The Brown Instrument Company of Philadelphia has presented some helpful suggestions for modifying their potentiometers in an article which appeared in their Bulletin No. B 15-10, entitled "Adaptability of the Measuring Circuit, Input Circuit and Amplifier of the Brown Electronik Potentiometer," by J. C. Mouzon. This company has also a new recorder which has a 2-second travel time and a 0.5-mv. span.

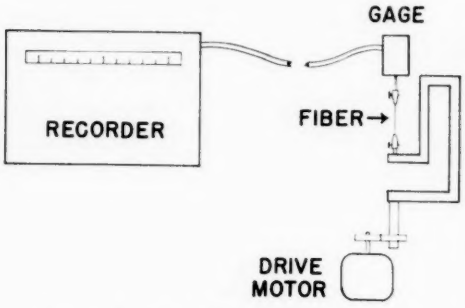

FIG. 1. *Schematic drawing of the fiber tester.*

FIG. 2. *Photograph of the tester.*

The rate of elongation, constant for any one test, can be varied widely through the use of gear reduction or by the choice of proper sample lengths. The maximum rate, of course, is determined by the speed of response of the recorder and by the Young's modulus of elasticity of the material under test. There are no physical limitations on the minimum rate of extension. The most commonly used rate of extension—8% per minute—makes possible the testing of samples having very high Young's moduli, such as fiberglas. Extreme care must be exercised in the construction of the drive mechanism; for single-filament work with samples approximately 1 inch in length the tester is sensitive to extremely slight variations in the speed of the drive motor or in the regularity of mechanical perfection of the advancing screw.

Figure 1 is a schematic drawing of the instrument. It consists essentially of three elements: the Statham gage, the drive motor, and the Brown recorder. The gage, drive-motor, and recorder controls are located on a panel on the recorder. The recorder chart drive and the sample drive motor can be synchronized to reverse simultaneously either by a manual control or by automatic controls set at adjustable stress limits. Figure 2 is a photograph of the instrument showing the setup used for ordinary yarn testing. A larger drive unit is used to test cords and fabrics. In the measurement of forces under 15 grams full scale it has been found advantageous to use a 10-to-1 balance lever in order to multiply the actual force on the gage. This could also be accomplished by the use of a pre-amplifier.

Examples of Results Obtained

A few of the results obtained by using this instrument are illustrated in Figures 3–7. The reproductions are from retouched prints of the original tracings made by the recorder on pieces of ordinary 8½ × 11-inch graph paper which were temporarily mounted on strips of chart with rubber cement. All data presented here were recorded at a constant rate of extension of 8% per minute.

In Figure 3 the dry curve (58% relative humidity) has a region in which the stress reaches a maximum, decreases to a minimum, and then increases again. This type of behavior can be observed in many fibers —another example being cellulose acetate. It would be impossible to obtain such a curve on a constant-rate-of-loading machine since in this test the load is never allowed to decrease. Thus, since the stress is not always a single-valued function, it is more illuminating to take stress-strain curves at a constant rate of extension. The wet stress-strain curve has a shape which is typical for many fibers and shows a strong sensitivity to inertia in the measuring mechanism. The usual incline-plane tester has enough inertia to give very misleading results for this type of measurement.

Another type of curve which shows a very small Young's modulus is that for a fabric. Figure 4 shows a typical stress-strain curve for a fabric and for a crimped yarn isolated from the fabric. This figure also illustrates the adaptability of the instrument to different force ranges. Although the forces for the two curves differed by a factor of 50, the scale was adjusted to give the same stress for both curves, thus making possible a direct comparison between them without replotting the yarn and fabric curves.

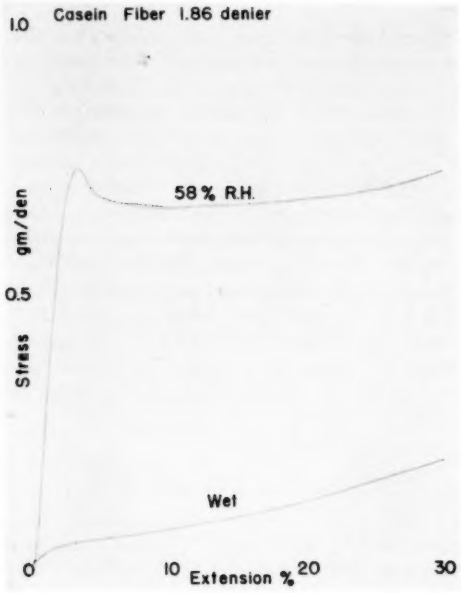

FIG. 3. *Stress-strain curve of a casein fiber wet and conditioned.*

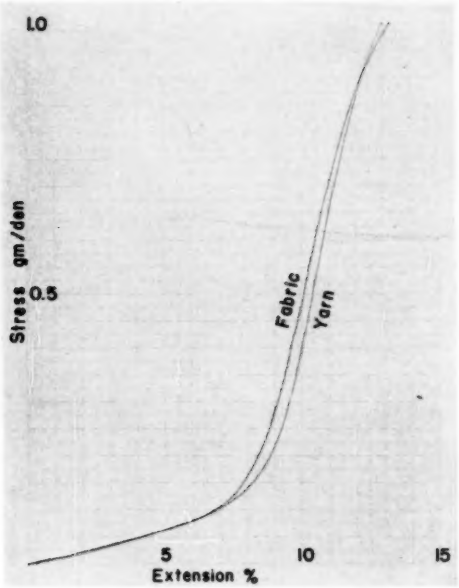

FIG. 4. *Stress-strain comparison between a fabric and a yarn isolated from the fabric.*

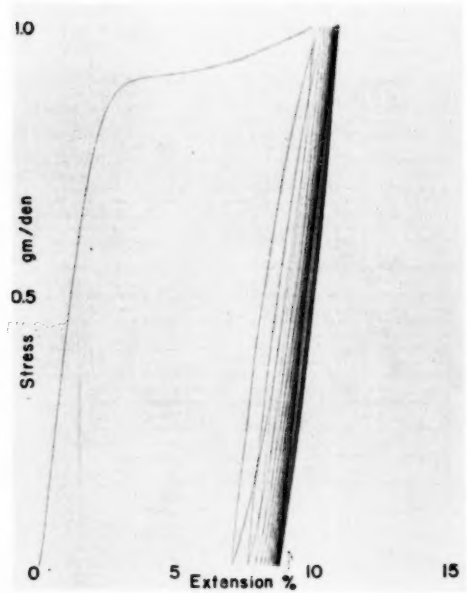

FIG. 5. *Stress-strain cycles between the stress limits of 0 and 1.0 gram per denier on a 75/20 cellulose acetate yarn.*

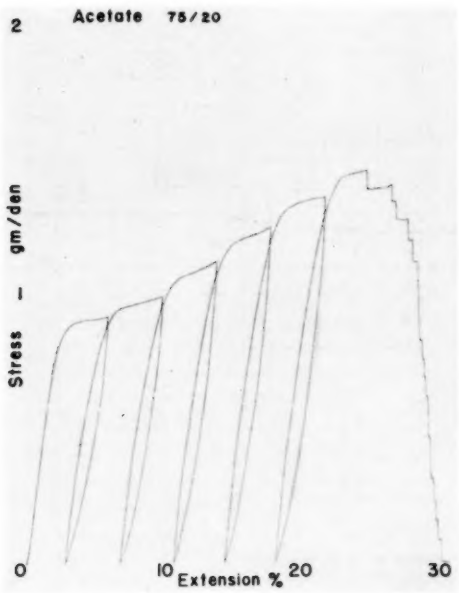

FIG. 6. *Stress-strain cycles to progressively larger extensions showing also the mechanism of break.*

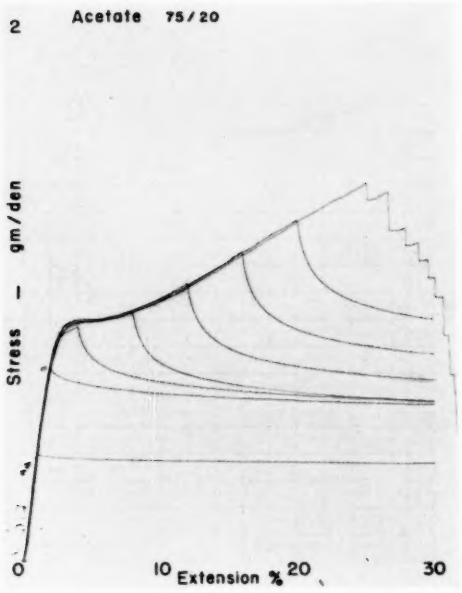

FIG. 7. *Stress relaxation at various extensions of a cellulose acetate yarn at 40% R.H.*

Figure 5 illustrates one type of cyclic process which this instrument can easily record. The instrument was set to reverse its motion automatically at two stress limits. Thus, the yarn in this case was subjected to repeated extension-retraction cycles between the limits 0 to 1 gram per denier. The accurate record is shown in this figure. Another type of process of some interest is that of hysteresis loops at progressively larger extensions. Such a record is shown in Figure 6. It also illustrates the process of breaking a yarn at constant rate of extension; this was a 75/20 acetate yarn. One can see from the curve the exact point where each of the 20 filaments broke. Thus, it is easy to study the uniformity of a yarn with respect to the breaking process by observing the distribution of breaking extensions of its component filaments.

In the study of the time-dependent phenomena of fibers the stress-relaxation at constant length is of great importance. However, one of the difficulties involved in a relaxation study is that of attaining in a unique manner the extension to be studied. This is very important since the relaxation behavior is quite sensitive to the manner in which the extension was attained. Figure 7 shows a convenient way of overcoming this difficulty. The sample is brought to the desired extension at constant rate of extension, the

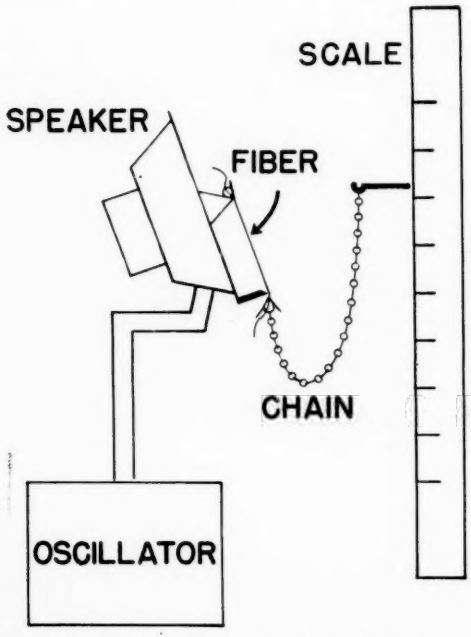

FIG. 8. *Schematic drawing of the vibrascope.*

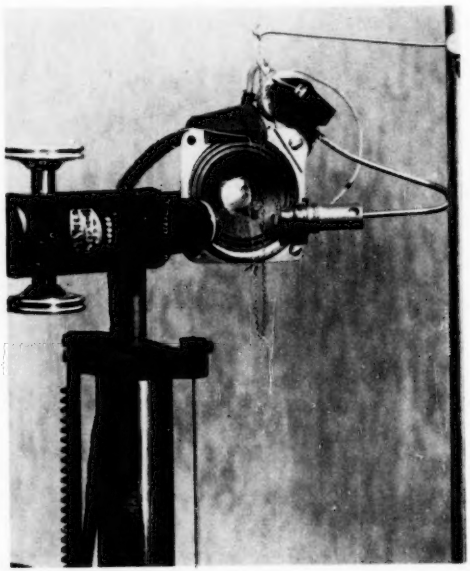

FIG. 9. *Photograph of the vibrascope.*

extension motor is stopped, and the stress recorder continues to plot the relaxation of stress at constant length. This can be accomplished automatically or manually. This procedure has the advantage of being a unique and reproducible technique in which a complete record may be obtained of the extension and stress at all times.

These are the main features of the fiber testing equipment and a few illustrations of its many possible applications. Emphatically, it is an excellent research tool, but it would not be well suited to routine testing because of its wide flexibility.

Vibrascope

A necessary accessory for measuring the denier of single filaments is the vibrascope similar to the "vibroscope" of Gonsalves (TEXTILE RESEARCH JOURNAL **17**, 369–75 (July 1947)). Following is a suggested improvement on the original model. The vibrascope is based on the relationship

$$m = \frac{P}{4l^2\nu^2}$$

which relates the linear density, or denier, m, with the tension, P, the length vibrating, l, and the frequency at resonance, ν. This is, of course, the same relation which governs the behavior of the vibrating strings on stringed musical instruments. Gonsalves used the frequency as his variable, which necessitated an expensive precision oscillator and vibrator and also gave him an inverse-square relationship between his variable and the denier.

In order to overcome these difficulties it seems better to hold ν constant (1000 ~) and let the tension, P, be the variable. This results in a linear scale, allows the use of less expensive equipment, and loads all filaments with the same relative amount (0.05 g. den.). A schematic drawing of the equipment is shown in Figure 8. The fiber is held at one end by a spring clamp on the vibrator (2-inch speaker) and at the other end by a spring clamp and the chain (~ 20 mg. cm.). The tension in the fiber is adjusted by the chain-o-matic principle to resonance and the denier is read directly from the calibrated scale. Figure 9 is a photograph of the instrument. The precision of the instrument is excellent. For uniform fibers denier can be read reproducibly to ± 0.01 denier, which corresponds to about 0.03 microgram weight in the 3-cm. sample.

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Method for Evaluating the Elastic Properties of Knitted Fabrics

Hazel M. Fletcher, Arnold M. Hansen,* and Mary Ellen Duensing*

Bureau of Human Nutrition and Home Economics, Agricultural Research Administration, U. S. Department of Agriculture, Washington, D. C.

Abstract

A device is described which was designed and built primarily for evaluating the visco-elastic behavior of knitted fabrics. This apparatus can be used in measuring the stretch and elastic recovery of knitted materials in either the lengthwise or crosswise direction or in both directions simultaneously when various loads are applied.

Measurements made with this machine are presented which show the relationship between strain and elastic recovery in plain knit fabrics of cotton, nylon, rayon, and wool. Elastic recovery values as determined on the new device are considerably higher than those obtained with the incline-plane serigraph machine commonly employed in determining the breaking strength and elongation of yarns. This difference in values is due to the fact that in the method using the incline-plane machine only the recovery which occurs instantaneously is measured, whereas with the new device it is possible to determine the combined instantaneous and delayed recovery.

A METHOD for measuring the stretch and elastic recovery in knitted fabrics by using an incline-plane serigraph machine commonly employed in the determination of the breaking strength and elongation of yarns has been described previously [1, 2]. This method measures only the instantaneous recovery since in one complete stress-strain cycle there are only one or two seconds in which no stress is exerted on the specimen. Furthermore, with this procedure it is impossible to measure the stretch and elastic recovery in both the lengthwise and crosswise directions simultaneously.

Since delayed recovery as well as the instantaneous recovery in knit fabrics determines the suitability of these materials for specific uses, a method is needed by which it is possible to evaluate the elastic properties under various conditions. Such a procedure has been developed and the necessary machine designed and built in the laboratories of the Bureau of Human Nutrition and Home Economics.

Apparatus

The top view of the aparatus before the fabric is inserted is shown in normal position in Figure 1. Figure 2 shows the apparatus in use. The framework of the machine consists of two parallel steel rails placed at right angles to two similar parallel rails, all of which are mounted rigidly on a flat wooden surface. On each side of the square formed by the intersection of the two pairs of parallel rails is mounted a hollow casing. Two of the casings are fastened to two trams, each of which is mounted on four wheels that, with the assistance of ball bearings, run freely on the parallel rails. The other two casings are stationary and are mounted adjacent on the other two sides of the square.

In each of the hollow casings are several segments. Each segment has attached to it a pointed steel needle approximately one inch long. Two brass bearings are mounted on each segment in order to allow free movement of the segments back and forth in the hollow casing. To each tram is fastened a cord which passes over a pulley. Loads of various sizes may be attached to each cord.

Operation of the Device

In operating the device approximately 12-inch squares of the fabric to be tested are placed on the pins as shown in Figure 2. Initial loads just sufficient to hold the fabric taut without distortion are applied in both the lengthwise and crosswise directions, and three lengths in each direction are marked off accurately on the test specimen (Figure 2). Loads are

* Resigned.

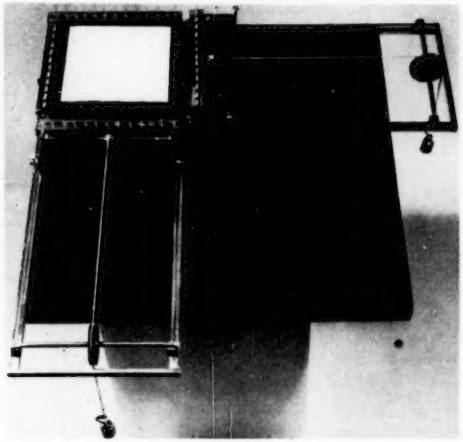

FIG. 1. *Top view of apparatus for measuring stretch and elastic recovery in knitted fabrics*

applied in the two directions and the marked lengths are measured. The two loads are then removed simultaneously, the small initial loads are applied, and the lengths and the widths of the areas are again measured. From these measurements the elastic recovery is calculated as the ratio of the recoverable stretch to the total stretch. Since several seconds—10 or more—were allowed for the fabric to return to its original dimensions, the calculated recovery was the combined instantaneous and delayed elastic recovery.

The apparatus has been tested in the Bureau's laboratory in which were maintained a relative humidity of 65 percent and a temperature of 70° F, the standard conditions for textile testing. The elastic recovery was measured in the crosswise direction for four plain knit fabrics knit with 32 courses per inch of the following commercial yarns:

36/1 medium-staple combed Peeler mercerized cotton
150-denier continuous-filament nylon
150-denier continuous-filament viscose rayon
1/52 wool

For the crosswise measurements the specimen was cut 12 inches by 8 inches with the shorter dimension parallel to the lengthwise direction of the knitted fabric. Figure 3 hows the specimen inserted on the pins of the apparatus. Twelve pins in a 5-inch length in each of the two casings hold the specimen in place.

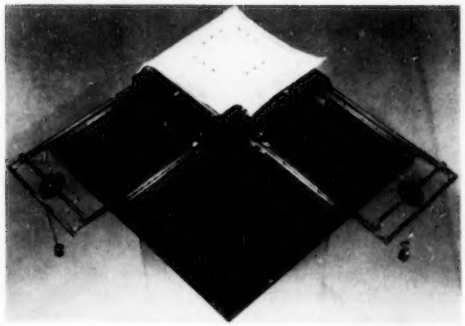

FIG. 2. *Apparatus with specimen of knitted fabric inserted and marked for measuring stretch and elastic recovery in both the crosswise and lengthwise directions.*

Three 5-inch lengths were marked off while the fabric was held taut by an initial load of 50 grams. The initial load was removed and a 200-gram load was applied. At the end of 10 seconds, readings were made of the three marked lengths. Then the 200-gram weight was replaced by the 50-gram weight. Fifteen seconds after the 200-gram weight was removed the readings were made in the same three places. From the measurements taken under different loads the total stretch, recoverable stretch, and elastic recovery were calculated. This procedure was repeated with loads of 300, 400, 500, 650, 800, 1,000,

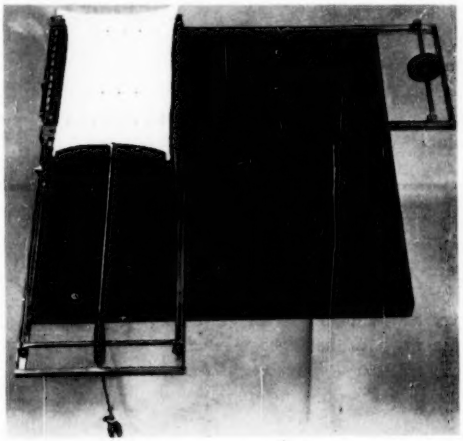

FIG. 3. *Apparatus with specimen of knitted fabric inserted and marked for measuring stretch and elastic recovery in the crosswise direction.*

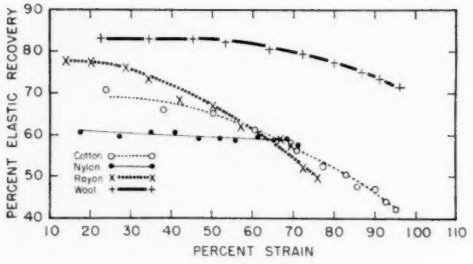

FIG. 4. *Elastic recovery-strain curves obtained with new machine for cotton, nylon, rayon, and wool knit fabrics in the crosswise direction showing combined instantaneous and delayed elastic recovery ranging from 83–42% and strain ranging from 12–95%.*

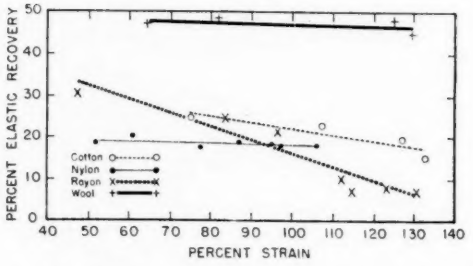

FIG. 5. *Elastic recovery-strain curves obtained with incline-plane serigraph machine for cotton, nylon, rayon, and wool knit fabrics in the crosswise direction showing instantaneous recovery ranging from 48–8% and strain ranging from 48–130%.*

1,250, 1,500, 1,750, and 2,000 grams using three specimens of each of the four fabrics.

Results

The relation between elastic recovery and strain of cotton, nylon, rayon, and wool knit fabrics in the crosswise direction is shown in Figure 4. These recovery measurements made on the new apparatus represent the combined instantaneous and delayed recovery. The recovery of the wool fabric was considerably greater than that of the cotton, the nylon, and the rayon. The recovery of the cotton and rayon fabrics decreased considerably with an increase in strain. Even though the nylon fabric had much less recovery for small strains, its recovery did not decrease with strain; for large strain it was somewhat superior to the cotton and rayon in this property.

Measurements of elastic recovery and strain for the same knit fabrics were made with the incline-plane serigraph machine. Graphs for these results are given in Figure 5. Since the data for this method had considerable variability, straight lines gave a better fit than curved ones. With both methods the elastic recovery of the wool was the greatest and the recovery of the nylon was the least for small strains. The wool and nylon materials did not decrease in recovery with an increase of strain over the range measured by the incline-plane machine. The cotton and rayon materials decreased in recovery with an increase in strain and for large strains had the least recovery. The wool was superior to all the other fabrics in this property.

Conclusions

A comparison of the results obtained by the two methods clearly reveals the influence of the time factor. The instantaneous recovery as measured with the incline-plane serigraph machine is considerably less than the recovery measured with the new apparatus. For a strain of 70 percent the instantaneous recoveries for the cotton, nylon, rayon, and wool fabrics studied were 26, 19, 26, and 48 percent, respectively, whereas the combined instantaneous and delayed recoveries were 58, 59, 55, and 80 percent, respectively.

These results indicate that delayed recovery is approximately equal to instantaneous recovery for cotton and rayon knitted fabrics. On the other hand, delayed recovery of nylon material is twice that of the instantaneous recovery, but for wool, instantaneous recovery is one and one-half times that of the delayed recovery.

The data obtained with the incline-plane serigraph machine were more variable than those obtained with the new machine. Furthermore, with the new device recovery for small strains can be measured. These measurements were impracticable with the serigraph machine.

Literature Cited

1. Hansen, Arnold M., and Fletcher, Hazel M., TEXTILE RESEARCH JOURNAL **16**, 571–5 (1946).
2. Fletcher, Hazel M., and Gilmore, Pearl A., *Rayon Text. Mo.* **28**, 476–8, 542–5 (1947).

(*Manuscript received October 7, 1948.*)

Discussion of Published Papers

"Measurement of Friction between Single Fibers: II: Frictional Properties of Wool Fibers Measured by the Fiber-Twist Method,"* by Joel Lindberg and Nils Gralén

Discussion of Paper

The above paper (hereafter referred to as *II*) reports a comprehensive examination by a new method of the frictional properties of the wool fiber. In general, the results agree with those obtained in this laboratory. (Most of the latter have been published previously [10]; a few are reported here for the first time.) However, certain points of agreement and disagreement warrant further discussion. First, it is desirable to summarize the major differences between the experimental conditions used in the two studies.

(*a*) In *II*, wool was rubbed on wool; in [10] on horn. The choice of rubbing surface has been explained in each case.

(*b*) In *II*, the apparent area of contact was considerably larger than in [10]. This reduced the variability of the measurements, so that fewer fibers had to be studied to obtain significant results: a definite advantage.

(*c*) In *II*, the total loads were of the order of a few grams; in [10] the highest load was 0.2 gram. The mean load per unit length of the fiber was also somewhat higher in *II* than in [10]. Rough calculation indicates that the distribution of load along the fiber was somewhat more uniform in *II* than in [10].

(*d*) In [10] considerably more attention was paid than in *II* to the condition of cleanliness of the rubbing surfaces, which was found to be very important, especially in connection with the form of the curve of $(\mu_2 - \mu_1)$ against pH.

One result found in both studies is that the coefficient of friction varies with the normal load (N_{tot} in *II*, L in [10]) or load per unit area (N in *II*) between the surfaces. Over at least a certain range of loads this variation can be represented by

$$\mu = a + b/N;$$

i.e.,

$$F = aN + b,$$

where F is the frictional force and a and b are constants. In *II*, following Gralén and Olofsson [5], this variation, in the case of μ_1, is ascribed to an intrinsic adhesion between the fibers. In [10] this was suggested as a possible explanation, but it was pointed out that other explanations would fit the data equally well. Experimental work on this question is under way.

The superficial resemblance of some of the curves of μ against $1/N$ in *II* to the curves of F against L in [10] could cause important differences to be unnoticed. Using the subscripts *1* and *2* to denote with- and against-scale motion, respectively, Figure 1(*a*) illustrates the case in which $a_1 = a_2$, $b_1 \neq b_2$, and Figure 1(*b*) illustrates the case in which $a_1 \neq a_2$, $b_1 = b_2$, drawn using the axes μ and $1/N$ used in *II*. Figures 1 (*c*) and 1 (*d*), respectively, show the same curves redrawn on the axes F and N ($\propto L$) used in

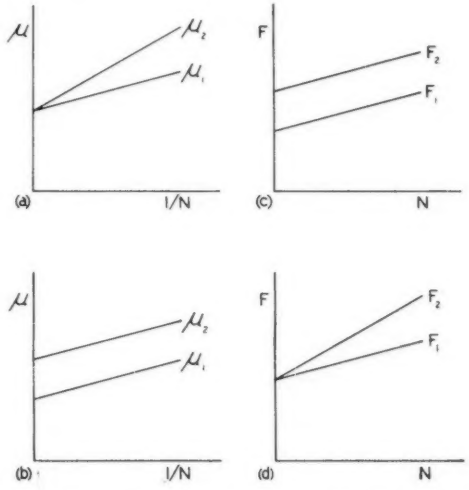

FIG. 1. *Curves of* $\mu = a + b/N$; *i.e.*, $F = aN + b$. (*a*) *and* (*c*): $a_1 = a_2$, $b_1 \neq b_2$. (*b*) *and* (*d*): $a_1 \neq a_2$, $b_1 = b_2$.

* TEXTILE RESEARCH JOURNAL **18**, 287 (May 1948).

[10]. All the curves obtained in the course of the work described in [10] approximated those of Figure 1(*d*) (Figure 6 in [10]); frequently b_2 was just a little greater than b_1. In *II*, curves corresponding to both Figure 1(a) and Figure 1(b) are given (Figures 9 and 11 and Figures 10 and 11, respectively, of *II*). The general trend of the curves in *II*, as of those given by Martin and Mittelmann [9], suggests that there is a change of type from that of Figure 1(b) or Figure 1(d) at low loads to that of Figure 1(a) or Figure 1(c) at higher loads.

The explanation of this change of slope given in *II* is plausible but difficult to test. Taking equations (*11*) to (*13*) of *II* as representing approximately the ratchet mechanism of the frictional difference (a more exact expression has been given elsewhere [8]), it can be seen that in order to calculate the range of N over which the change in slope should occur it would be necessary to know the true area of contact between the surfaces and their micro-elastic properties. If the explanation in *II* is correct, one would expect this range to be to a first approximation independent of the apparent area of contact, in which case the change of slope should be visible in Figure 10 as well as Figure 11.

The more detailed consideration [8] of the ratchet mechanism of the frictional difference leads to the suggestion that, if the explanation in *II* is basically correct, it may be the average scale resistance, Q, rather than the number of active scales, cA, which increases with N, since at high N a bigger volume of the scale edge would have to be deformed to permit against-scale motion.

Finally, in this connection, it should be noticed that there is little physical significance in the two observations emphasized on page 298 of *II*, that under certain conditions $\mu_1 = \mu_2$ and $\mu_s = \mu_k$, since in both cases this result arises merely from the fact that N is infinitely large. In neither case are the corresponding frictional forces equal (*cf.* Figure 1).

In connection with the variation of μ with pH, discussed in *II*, it has been found in this laboratory that sulfuric acid at pH 1 produces an irreversible decrease in both μ_1 and μ_2 for clean fibers, whereas an HCl-KCl buffer solution at the same pH produces a completely reversible increase. Sulfuric acid is therefore an unsuitable material to use in studying the effect of pH variation on the frictional properties.

In *II* it is shown that anti-felting treatments such as those with melamine resins do not act by "masking the scale structure." This is important, for although some authors [1, 4] realize this, the older view [2] is still often quoted [3]. It has been found here also that Lanaset does not materially reduce the frictional difference; nor does anhydrocarboxyglycine. The results obtained here are given in Table I. It will be seen that even in the case in which $(\mu_2 - \mu_1)$ was reduced by the treatment, the reduction was far too small to account for the effectiveness of the anti-felting treatment. (For each treatment a staple of wool was treated together with a knitted square of fabric; the fact that felting of the latter had been almost eliminated was checked by hand-washing.) It appears obvious, if an attempt is made to pull a fiber out of a treated fabric or staple, that the fibers are "glued" together by such treatments.

TABLE I*

Treatment	Conditions of measurement of μ	μ_1	μ_2	$\mu_2-\mu_1$	δ
None	pH 7, clean [10]	.53	.95	.42	.28
Lanaset	pH 7, clean	.41	.74	.33	.29
Anhydro-carboxyglycine	Tapwater (pH 6.5)	.46	.87	.41	.31
None	Air-dry	.26	.51	.24	.31
Lanaset	Air-dry	.23	.50	.27	.37
Anhydro-carboxyglycine	Air-dry	.23	.51	.28	.38

* Each value is the mean of about 50 measurements on from 2 to 5 different fibers.

Measurements made in this laboratory do not, however, agree with those described in *II* for the benzoquinone treatment. As reported in detail elsewhere [8], it was found that μ_1 and μ_2 at pH 7 are decreased by the treatment and $(\mu_2 - \mu_1)$ and δ are increased. In *II* it is reported that in distilled water all the coefficients are slightly decreased. A difference in the degree of cleanliness of the surfaces may be important in this connection, as can be seen from the data given in [8]. Further experiments are needed.

I am indebted to Miss A. Dunbar for making some of the new measurements reported here, which were carried out as part of the program of research of the Division of Physics of the Council for Scientific and Industrial Research, Australia.

K. RACHEL MAKINSON

Research Officer, Division of Physics, National Standards Laboratory, Council for Scientific and Industrial Research, Commonwealth of Australia

(*November 3, 1948*)

Authors' Comments

We are grateful for the opportunity of reading Mrs. Makinson's discussion. We should like to add only a few comments.

We have previously worked with a stick-slip apparatus [5], similar to that used by Mercer and Makinson [10]. The apparatus used in *II* was constructed partly in order to avoid some of the difficulties connected with the former one. One of these was the difficulty of immersing the fibers in a liquid, a problem solved in [10] by the application of a drop of the liquid at the contact point. Another difficulty was supposed to be avoided in [10] by replacing one of the fibers by a piece of polished horn, which should have a surface similar to that of the wool fiber. We have found since, however, that the surface of the wool fiber is covered by a thin skin which has properties different from the wool keratin, and therefore the two surfaces cannot be similar [7].

We have found that a commercially scoured fiber is sufficiently clean to give reproducible results in our apparatus, and no noticeable change is obtained by further cleaning. However, it is obvious that the fibers should be as clean as possible.

Unfortunately, Mrs. Makinson seems not to have read our third paper in the series [6], in which some of the experiments are repeated and fuller results are reported. We want to point out that the curves μ_2 vs. $1/N$ cannot be represented by the simple formula

$$\mu = a + \frac{b}{N},$$

where a and b are constants. Equation (13) in *II* is of the form

$$\mu_2 = a + \frac{b}{N} + \frac{F_s}{N}.$$

As shown in Figure 2 of [6], F_s is a function of N and hence is not constant. Therefore the curve μ_2 vs. $1/N$ should not be a straight but a curved line, as shown in Figure 1 of [6]. It is a straight line and is parallel to μ_1 only when F_s is proportional to N, which might be true at low values of N.

The discussion about the frictional coefficients for an infinitely large N is purely academic. We have shown that it is impossible to measure the friction at higher normal pressures without causing too much abrasion, thus altering the original surface. The essential thing is that the scale resistance is of less importance for the friction when N is large.

TABLE I. FRICTIONAL COEFFICIENTS OF DIFFERENT FIBERS

Nylon, dry		0.40–0.45
Natural silk, dry		0.50–0.60
Viscose rayon, dry		0.30–0.40
Wool, dry		0.10–0.15
Wool, wet	μ_1	0.15–0.25
	μ_2	0.30–0.45

The observation of the irreversible changes produced by sulfuric acid is very interesting. It would be of interest to know if this observation is true also for the friction of wool against wool, or if the irreversibility is to be found in the horn keratin.

In the case of the anti-felting treatment of the wool with resins, we have also found that the effect is at least partly, and possibly primarily, due to a gluing of the fibers to decrease their mobilities. We have made a separate investigation of this and the results will soon be published.

In the case of anhydrocarboxyglycine, however, we got a considerable increase in the frictional coefficients both in the wet and the dry state. The difference between μ_2 and μ_1 was also partly eliminated. The treatment (sample obtained from Prof. J. B. Speakman, Leeds, England) was made in a 4% solution of the reagent. The discrepancy between Makinson's and our results might be due to differences in the treatments.

There is one very important difference between the results obtained by Makinson *et al.* and by us, not mentioned in her remarks. All the values of the frictional coefficients of wool (wet and dry) reported by her are considerably higher than ours. For other fibers, such as nylon, our values are higher than hers. Table I above should be compared with data of Table 1 in [10]. The differences might probably be explained by the difference between methods of measurements.

JOEL LINDBERG
NILS GRALÉN
Swedish Institute for Textile Research,
Gothenburg, Sweden

(*November 25, 1948*)

Literature Cited

1. Baldwin, A. W., Barr, T., and Speakman, J. B., *J. Soc. Dyers and Colourists* **62**, 4 (1946).

2. Barr, T., Capp, C. W., and Speakman, J. B., *J. Soc. Dyers and Colourists* **62**, 338 (1946).
3. Carter, E. G. H., *Textile Manufacturer* **72**, 258 (1946).
4. Dudley, J. R., and Lynn, J. E., "Symposium on Fibrous Proteins," Soc. Dyers and Colourists, May, 1946, p. 215.
5. Gralén, N., and Olofsson, B., TEXTILE RESEARCH JOURNAL **17**, 488 (1947).
6. Lindberg, J., TEXTILE RESEARCH JOURNAL **18**, 470 (1948); *Proc. Swed. Inst. Text. Res.*, Nr. 8, (1948).
7. Lindberg, J., Philip, B., and Gralén, N., *Nature* **162**, 458 (1948). *Cf.* Lindberg, J., TEXTILE RESEARCH JOURNAL **19**, 43 (1949).
8. Makinson, K. R., *Trans. Faraday Soc.* **44**, 279 (1948).
9. Martin, A. J. P., and Mittelmann, R., *J. Text. Inst.* **37**, T269 (1946).
10. Mercer, E. H., and Makinson, K. R., *J. Text. Inst.* **38**, T227 (1947).

"Constitutional Factors in the Production of Artificial Protein Fiber,"* by Sam R. Hoover, Elsie L. Kokes, and Robert F. Peterson

The Entropy Contribution to the Load in Stretched Casein

In the above paper the authors discuss some results of mine relating to the entropy and internal energy contributions to the load on stretched casein fibers (*J. Colloid Sci.* **1**, 407 (1946)). With their notation the total load, F, may be written as the sum of F_s, the entropy term, and F_u, the internal energy term; I found that at low extensions (up to 25% in some fibers) F_u was negative, becoming positive at higher extensions, and I coined the phrase "hyperentropic" to describe the state of affairs where $F_s > F$. Describing experiments of their own on acetylated casein, Hoover, Kokes, and Peterson state (p. 426): "We did not observe the anomalous hyperentropic effect found by Woods." This statement was surprising as I had already noted that in their Figure 2 the authors had plotted a curve for F_u vs. elongation in which negative values are shown for extensions up to about 10%, and I was congratulating myself on an independent confirmation that such an effect occurs, admittedly over a lower extension range, but this might easily happen in a fiber so notoriously variable as casein.

I have already pointed out (*loc. cit.*) that in at least one other fiber, nylon, a negative initial value of F_u is observed, but only over an extension range of some 4%. I should like to add that I have results for "elastic" nylon which show the effect for extensions up to 40%.

H. J. Woods
Textile Physics Laboratory,
The University, Leeds, England

(October 29, 1948)

Authors' Comments

We appreciate Dr. Woods' comments on our paper. The magnitude of the effect we observed was small. It was relatively consistent in various experiments and may well be a real effect. On the other hand, the small magnitude leaves open the possibility of a systematic error of manipulation or of the instrument. Our main point in this connection was that the calculated entropy load was not several times the total load at extensions up to 20% (three times the observed tension at 10% elongation) as Figure 6 of Dr. Woods' paper indicates.

SAM R. HOOVER
ELSIE L. KOKES
ROBERT F. PETERSON
Eastern Regional Research Laboratory,
Philadelphia 18, Pa.

(November 23, 1948)

* TEXTILE RESEARCH JOURNAL **18**, 423 (July 1948).

Book Reviews

Rayon Technology, Handbook for Textile Mills. Prepared by the Textile Research Department of American Viscose Corporation. New York, McGraw-Hill Book Company, Inc., 1948. 273 + vii pages. Price, $3.75.

(Reviewed by Chapin A. Harris and Jacob K. Frederick, Jr., Lowell Textile Institute, Lowell, Massachusetts)

This book is the combined work of various members of the Textile Research Department of American Viscose Corporation, each a specialist in his own field.

The arrangement of the text follows the general organization of the textile industry in that sections are devoted to the following phases: (*a*) Rayon Staple on the Cotton Sytem, (*b*) the Worsted System, and (*c*) the Woolen System; Rayon from Yarn to Fabric; Standard Rayon Fabric Constructions; Rayon in Knitting Mills; and Rayon Dyeing and Finishing. This organizational approach has naturally resulted in some duplication of material, but it does have the advantage of furnishing the reader of a given section complete information on each subject.

A few errors are apparent. For example, on page 26, the spinning systems illustrated have their titles reversed (H. & B. illustration is really that for Saco-Lowell). Also, on page 86, the dimensions given for the cake insert are actually those for a cube, which is not the shape of the flat rectangular insert. On page 99, "cones" is used for "cakes."

Some improvement could be made if another edition were to be issued. For example, a uniform standard of abbreviations throughout the book and some clarification of terms having the same or related meanings in the textile industry would make for easier reading and less confusion even for experienced mill men. On page 104, the serious disadvantage of excessive shrinkage in garments cut from over-stretched rayon fabric should be pointed out.

The section devoted to rayon dyeing and finishing tends to minimize the effect of some procedures; for example, little mention is made of the delustering effect of dye baths at high temperatures on acetate, nor is the saponification of acetate with respect to dyeing and finishing mentioned. The details with respect to shrinkage control methods for rayon fabrics are excellent; however, little notice is given to the fact that the Definized and Glyoxal processes can result in considerable strength losses unless great care is exercised, and that these two processes result in some loss in initial strength under the best of conditions. The observations with respect to the Glyoxal process under multiple launderings are most interesting.

The good points of the book far outweigh the flaws mentioned here, for the technical information is essentially correct, and some of the tables, especially with respect to fabric defects and rayon fabric constructions, are most worth while. The details with respect to knitting and finishing are very capably handled, and set a high standard of readability. The index is most complete, and should prove of value in locating any subject quickly because of the many cross-references.

This book is definitely not designed for the novice, because of the lack of sufficient introductory information on many of the subjects discussed, but, then, it was written primarily from the viewpoint of bringing to the attention of the experienced mill man information relative to the handling of rayon in staple and filament form, and it has succeeded in so doing.

All in all, this book should find a place on the desk of every mill man engaged in handling rayon in any form, and the Textile Research Department of the American Viscose Company can rest secure in having made a worth-while contribution to the literature of textiles.

Surface Chemistry for Industrial Research. J. J. Bikerman. New York, Academic Press, Inc., 1948. 464 + ix pages. Price, $8.00.

(Reviewed by Earl K. Fischer, Institute of Textile Technology, Charlottesville, Virginia)

The author of this book, Dr. J. J. Bikerman, collaborated with the late Herbert Freundlich in his monumental *Colloid and Capillary Chemistry*. The present volume has very nearly the same scope as

Freundlich's treatise, but the purpose differs in its emphasis on the industrial applications of surface chemistry.

The subject matter is presented in six chapters, five of which refer to type of interface—*e.g.*, liquid-gas, liquid-liquid, etc.—with the sixth chapter devoted to electrical phenomena at interfaces. The author has attempted to bring scientific information to bear on many practical problems. In his search for material he has been only partially successful, however, for many industrial processes, especially those dealing with colloidal properties, are still operated on a perspicacious but highly empirical basis. The discussion includes underlying theory. Numerous drawings aid the exposition. Extensive citations to the literature document the volume. Nevertheless, it is likely that some readers will find the mode of presentation unfamiliar and the selection of topics somewhat eclectic. Surface-tension data, for example, are presented in "g. sec.$^{-2}$," instead of in the dimensionally equivalent and more familiar "dynes per cm." The contribution of electron microscopy to particle-size measurements, an important field in which notable advances have been made in the past decade, is given scant attention. Numerous contributions from certain industries, of which paint and rubber technology may be cited, have not been noted. Some omissions are undoubtedly dictated by the exigencies of space, and some, as the author notes in the preface, by failure of technologists to study a process in the light of existing knowledge and to publish their findings.

There is an abundance of material in this volume which has not been assembled elsewhere. It is presented in a terse style which makes reading slow but provides a compact compendium of useful source material. The investigator and student of surface and colloid chemistry will find this book of great interest.

A Comprehensive Dictionary of Textile Terms. Alfred Higgins and Rudolph L. LaVault. Fall River, Mass., Dover Press, 1948. 139 pages. Price, $5.00.

Although the authors indicate that this textile dictionary confines itself to "the most important and most widely used terms in the various textile industries and allied fields," nevertheless the work is more comprehensive than might be indicated by the number of pages.

The dictionary is the result of 20 years of recording and collecting on the part of the senior author. The definitions are concise, for the most part adequate, and have been brought well up to date. The typography and general format are excellent and make for easy scanning. All in all, this book should prove of value to all persons whose interests are in any way connected with textiles.

American Standard Letter Symbols for Physics: ASA (American Standards Association) Z 10.6–1948. New York, American Society of Mechanical Engineers, 1948. 37 pages. Price, $1.00.

This is the newest addition to the standards for letter symbols, abbreviations, graphs, and charts published from time to time under the procedure of the American Standards Association. Thirty-six national societies, associations, and governmental departments took part in the work which resulted in the agreements on the standard symbols.

Through cooperating with committees developing symbols in other fields, an attempt has been made to develop symbols that can be used for the same idea in all fields wherever possible. All common terms in elementary physics and some in advanced physics and related fields are included. Most symbols in mathematics, crystallography, meteorology, x-rays, statistics, etc., have been omitted.

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A list of periodicals, the abbreviations used in reference to articles, and the addresses of publishers of English-language publications is given in the January, 1949, issue, page 46.

ANALYSIS: TESTING: LABORATORY METHODS

★

Estimation of Cellulose

A new method for the estimation of cellulose, with special reference to jute. Hrishikesh Chattopadhyay and P. B. Sarkar. *Proc. Natl. Inst. Sci. India* **12,** 23–46 (1946); cf. *C.A.* **39,** 2871[2] (through *Chem. Abstr.* **42,** 4343*d* (June 20, 1948)).

Methods of determining cellulose are critically reviewed, but the data given by the authors deal largely with the determination of holocellulose (*I*) in jute by the chlorite procedure. The influences of temperature, time, liquor ratio, and concentration were studied. Extractive-free jute, when treated with 0.7% $NaClO_2$ (at pH 3–4) for 2 hrs. at 98–9°C, with a liquor ratio of 1:50 (or with 3.5% $NaClO_2$ at 60–70°C and pH 4), gave a fibrous residue, which when washed with aqueous $NaHSO_3$ and H_2O and dried *in vacuo* gave nearly the theoretical yield of *I*, retained very little lignin, and showed relatively slight losses in furfural-yielding or CO_2-yielding material. The method could also be applied to paddy straw, but proved unsatisfactory for pinewood (the *I* of which still retained 8.9% lignin). Whatman No. 42 filter paper, when chlorited, lost only 0.4–0.6% and showed relatively little change in Cu no. or methylene blue absorption. In the authors' opinion, no sharp line can be drawn between the cellulosans and other hemicelluloses. 26 references.

Text. Research J. Feb. 1949

Barium Carboxymethyl Cellulose

Barium carboxymethylcellulose—a thixotropic gel. Sven Sönnerskog. *Svensk Papperstidn.* **50,** 445–6 (1947) (in English) (through *Chem. Abstr.* **42,** 2766*f* (Apr. 20, 1948)).

The Ba (*I*) of carboxymethylcellulose prepared by adding an equivalent amount of a H_2O-soluble Ba salt to an aqueous solution of Na carboxymethylcellulose (*II*) is a slightly dissociated salt which is a thixotropic colloid. The corresponding Ca salt has higher solubility and degree of dissociation. *I* is a good film-forming material and gives greaseproofness when coated on paper or board. The thixotropic properties make *I* useful as an additive to paint and printing ink. The specific properties of the Ba salt are used to indicate the structure of some cellulose ethers. Examples for this are given in reaction between *II* and ethylene chlorohydrin and between *II* and β,β-dichlorodiethyl ether.

Text. Research J. Feb. 1949

Copper Number of Cotton

Glucides. I. Copper number of spun unbleached cotton. Alfred Leman and Maurice Aubourg. *Bull. soc. chim. France* **1947,** 980–4 (through *Chem. Abstr.* **42,** 5670*c* (Aug. 10, 1948)).

The Cu number was determined with the cupricarbonate reagent of Braidy (*C.A.* **15,** 2360) according to the technique used in the Explosives Bureau (*cf.* Brissaud, *C.A.* **29,** 6046[2]). Recently spun cotton had a Cu number of 0.54 and a 6-year-old sample 0.43, both on an air-dry basis. The precision of these measurements was 10%. Data are presented which confirm the empirical nature of the determination and the necessity of employing a uniform technique. At boiling water temperature the reaction is two-thirds complete in about 1 hr. and may

be considered complete in 3 hrs. These are the conditions used in the determination. At the boiling temperature of the reagent the Cu number increased continuously with time. For equal time of reaction the Cu number was higher, the higher the temperature and the greater the quantity of Cu reagent used.

Text. Research J. Feb. 1949

Measurement of Fiber Fineness

A permeability method for determining fiber fineness. John P. Elting and James C. Barnes. TEXTILE RESEARCH JOURNAL **18,** 358–66 (June 1948).

An instrument to measure the air permeability of compressed fiber wads is described, together with essential details of construction. An index, *F*, of fiber fineness is defined following the derivation of an approximate permeability. The roles played by porosity of the plug, the size, shape, and density of the fibers, and their effect on the values of *F* are discussed with reference to cotton. Errors due to sample weight, moisture, and trash are appraised. An estimate of the instrument precision is obtained by analysis of experimental data. The nature of results obtained from measurements on cotton is described; typical ranges of *F* observed for several varieties of cotton are noted. Authors

Text. Research J. Feb. 1949

Horn Keratin's Elastic Properties

Determination of the elastic properties of horn keratin. F. L. Warburton. *J. Text. Inst.* **39,** P297–307 (July 1948).

Methods used for determining Young's modulus and Poisson's ratio for horn keratin are described. The effect of humidity on the relative values of the tangential Young's modulus is discussed. Data for Poisson's ratio are limited to the value at room humidity for the contraction produced in the tangential direction by longitudinal stresses. L. P. Witnauer

Text. Research J. Feb. 1949

Photomicrography

Photomicrographs tell a story. Anon. *Textile Inds.* **112,** 119–22 (Sept. 1948).

Microscopy and photomicrography are being used in the textile industry on an increasing scale not only in fundamental research but also in development, production control, and competitive product evaluation. The microscope may be used to identify a fiber, estimate its maturity, detect rayon, and to distinguish between bright and dull rayon. The relative fiber diameter of rayon is easily measured and its proper denier determined. Tests may be carried out with fibers in yarn and fabrics using the microscope and photomicrograph to check blending efficiency, identify the fibers in the blend, and to study the behavior of the yarn when woven. A. L. Landau

Text. Research J. Feb. 1949

Reactivity of Dissolving Pulp

Technology of lignified cell walls. Determination of the reactivity of technical cellulose, especially beech sulfite pulps, on xanthogenation. W. Klauditz and K. Berling. *Cellulosechemie* **22,** 121–32 (1944) (through *Chem. Abstr.* **42,** 4344*c* (June 20, 1948)).

A rapid laboratory method was devised for determining the reactivity of dissolving pulps.

Text. Research J. Feb. 1949

Metallic Shadow-Casting

An electron-microscopical examination of rayon. Charles W. Hock. TEXTILE RESEARCH JOURNAL **18,** 366–71 (June 1948).

By metallic shadow-casting of specimens for electron-microscopical examination, fibrils a few hundred Ångstroms in diameter were demonstrated in cuprammonium and in viscose rayons. Fibrillation was more distinct in the rayons having a high degree of orientation. The fine fibrils in the fibers of both these regenerated celluloses were similar to those previously observed in native cellulose fibers. A comparison of surface replicas of the fibers revealed distinct differences. Whereas the cuprammonium rayon fibers were relatively smooth, except for occasional markings which gave them a scaly appearance, the viscose rayon fibers were rougher, and showed irregular netlike patterns. Author

Text. Research J. Feb. 1949

Electron Microscopy

Adjustable aperture for electron microscope, RCA-type EMU. John T. Ouynn. *Rev. Sci. Instruments.* **19,** 472–3 (July 1948).

A new adjustable mounting device for the objective aperture of an RCA-type EMU electron microscope is described and illustrated. L. P. Witnauer

Text. Research J. Feb. 1949

X-Ray Diffraction

X-ray diffraction as a tool in the study of textile fibers. J. F. Whitney. *The Frontier* **11,** No. 2, 18–23 (1948) (through *Chem. Abstr.* **42,** 6541*a* (Sept. 10, 1948)).

A discussion of the diffraction pattern, the x-ray fiber diagram, and the structure and mechanical properties of fibrous materials.

Text. Research J. Feb. 1949

CHEMICAL AND PHYSICAL RESEARCH

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Amylopectin

Isomerism of amylopectins. Maks Samec. *Akad. Znanosti Umetnosti Ljubljani, Kem. Lab., Kem. Studije* (Yugoslavia) **1947,** 76–84 (through *Chem. Abstr.* **42,** 4774*h* (July 10, 1948)).

The electrodialysis and electrodecantation of starch solutions yielded amyloses and amylopectins. The

amyloses prepared from different starches were identical. Amylopectins prepared from different starches were not identical. Potato amylopectin prepared by electrodialysis is mucous, thready, and almost transparent, can be concentrated to 8%, becomes violet with dilute I and red with an excess of I, has a higher viscosity than the corresponding corn amylopectin, and combines with H_2O. Corn amylopectin prepared similarly is white, lumpy, and opaque, may be concentrated to 5%, becomes blue with a trace of I and green with an excess of I, and combines with H_2O. The phosphorylyzed corn amylopectin became a jelly when concentrated to 1.2% and combined with H_2O. Although some of the differences between amylopectins is due to the presence or absence of ester-like combined phosphoric acids and also of groups containing N and P (phosphatides), most of the difference is due to the length of the hexose chains between the points of branching. Analyses indicate that 40% of the molecules of amylopectin consist of side chains, 5% of the potato amylopectin molecules consist of end groups and 3.5% of the corn amylopectin molecules consist of end groups. A molecule of amylopectin consisting of 200 hexose units will have 80 hexose units in side chains. The potato amylopectin will have 12 side chains with 7 hexose units to the chain. The corn amylopectin will have 8 side chains with 10 hexose units to the chain.

Text. Research J. Feb. 1949

Cellulose Degradation

Cellulose behavior with filtered sunlight. P. J. Fynn, J. E. Sands, and K. S. Campbell. TEXTILE RESEARCH JOURNAL **18,** 350–7 (June 1948).

Simultaneous exposures of several different samples from the same piece of kier-boiled cotton sheeting were made in sunlight both under fairly well-controlled and under uncontrolled conditions. The controlled exposures were made in a specially constructed cabinet designed to segregate sunlight from other factors of weathering and inside which the samples were kept flat and perpendicular to the sun's rays during exposure. The uncontrolled exposures were made on open racks, some maintained at normal incidence, some vertically north, and others inclined 45° to the south. A comparison of samples from controlled and uncontrolled exposures indicated that, in the absence of any pronounced microbiological action or damage obviously due to corrosive atmospheric contaminants, sunlight can account for practically all of the degrading effects on cotton fabrics caused by prolonged weather exposure. Considerable acceleration of effect is accomplished by maintaining the sample surfaces perpendicular to the sun's rays. A "degradative index" was computed from the data which gages the degrading efficiency of light as transmitted by the different filters. It is shown that the degrading influence of solar radiation is not limited to the short-wave portion of the spectrum. From comparison of the difference in effect on cellulose of solar energy from separate spectral regions acting individually and in combination, evidence is presented which indicates the existence of an antagonism between energies from different portions of the spectrum. Authors

Text. Research J. Feb. 1949

Nitration of Cellulose

Esterification of cellulose. II. Mechanism of nitration. J. Chédin. *Mém. services chim. état.* (Paris) **32,** 108–34 (1945); cf. *C. A.* **40,** 7614[1] (through *Chem. Abstr.* **42,** 4746*a* (July 10, 1948)).

A mechanism is proposed for the nitration of cellulose by a mixture of H_2SO_4 and HNO_3. In the crystalline portion of the cellulose, the planar HNO_3 molecules diffuse faster and nitrate most of the OH groups at a given point before the more bulky H_2SO_4 molecules reach the point. As the H_2SO_4 approaches the point, it is not attracted by the small number of OH groups remaining and has no tendency to diffuse into the crystalline region which is already filled with HNO_3. The noncrystalline portion of the cellulose is nitrated by the sulfonitric mixture. The HNO_3 is held tightly in the crystalline area and is not removed by pressing. An equation is developed for calculating the ratio of crystalline to noncrystalline cellulose in a given sample.

Text. Research J. Feb. 1949

Nitration rate of cellulose: activation phenomena. A. Tribot and J. Chédin. *Mém. services chim. état.* (Paris) **32,** 135–44 (1945) (through *Chem. Abstr.* **42,** 4746*c* (July 10, 1948)).

The addition of H_2O or C_5H_5N to cellulose increases its rate of nitration by a sulfonitric bath. The maximum rate is given by 1 molecule of H_2O or 0.2 molecule C_5H_5N per glucose unit. Apparently the activators break the secondary bonds between the OH groups in cellulose and make the OH groups more accessible to the nitrating agent. It is possible that the H_2O or C_5H_5N becomes attached to the OH groups and then attracts the HNO_3 and H_2SO_4.

Text. Research J. Feb. 1949

Manufacture of nitrocellulose of twelve and thirteen percent nitrogen. Relation between composition of the sulfonitric bath and the properties of the cellulose nitrate. A. Tribot and A. Marsaudon. *Mém. services chim. état.* (Paris) **32,** 145–56 (1945) (through *Chem. Abstr.* **42,** 4746*d* (July 10, 1948)).

One part dry American linters and 50 parts of a mixture of HNO_3, H_2SO_4, and H_2O (varying composition) were allowed to react 1 hr. at 30°C. A bath of HNO_3 59, H_2SO_4 28.5, and H_2O 12.5% gave the product with highest viscosity. Higher percentages of HNO_3 gave harsh, brittle material, with evident degradation. Baths weak in HNO_3 (below 30%) and strong in H_2SO_4 react slowly and give more combined H_2SO_4 in the final product, which decreases its stability.

Text. Research J. Feb. 1949

Certain facts and hypotheses concerning the stabilization of cellu-

lose nitrate. J. Chédin and A. Tribot. *Mém. services chim. état.* (Paris) **32,** 157–67 (1945) (through *Chem. Abstr.* **42,** 4746*f* (July 10, 1948)).

The instability of cellulose nitrate (*I*) is usually attributed to the residual H_2SO_4 remaining after nitration and preliminary washing. The question of whether the H_2SO_4 is held mechanically or chemically has not been answered. When *I* is treated with H_2O at 100°C, H_2SO_4 and HNO_3 are removed in a molecular ratio of about 1 to 7 until all H_2SO_4 is removed; after 90 hrs. HNO_3 is removed from *I* in 10 hrs. if no H_2SO_4 was used in its preparation. These facts support the theory that the H_2SO_4 is held in the form of a sulfonitric ester of cellulose. However, the fact that H_2SO_4 is removed from *I* by dissolving in Me_2CO and reprecipitating in H_2O supports the idea that it is mechanically held.

Text. Research J. Feb. 1949

Alkali Absorption by Cellulose

The role of water during the absorption of sodium hydroxide by cellulose. Geneviève Petitpas and Thérèse Petitpas. *Compt. rend.* **226,** 672–3 (1948) (through *Chem. Abstr.* **42,** 4744*a* (July 10, 1948)).

In the absorption of aqueous NaOH solution by cellulose, the quantity of NaOH retained by the cellulose increases as the concentration of the aqueous NaOH solution increases, whereas the quantity of H_2O retained passes through a maximum at a concentration of about 4 *N* (14%). When H_2O is replaced by MeOH, the retention is very small and only shows a slight indication of a maximum. When H_2O is added to the mixture of NaOH-MeOH, the retention is larger and increases more rapidly in proportion to the concentration. A diagram representing the absorption of NaOH (as calculated from the titer) as a function of the concentration of the solution gives a curve with a flat between 4 and 6 *N* (14–20%) and another less distinct one between 7 and 8 *N* (23–24%). When H_2O is replaced by MeOH, the absorption is very weak and shows a maximum at 3 *N*. The x-ray diagram of the cellulose-NaOH aggregate indicates a close connection between the structural change and the course of the retention and absorption curve. As it is known, H_2O by itself does not change the crystalline system of the cellulose. The penetration into the crystalline system begins at about 4 *N* (14%), which coincides with the first flat in the absorption curve. At the same time the retention of H_2O decreases and the retention of NaOH increases. The second modification in the x-ray diagram occurs at 7.5 *N* (24%) when the H_2O retention is almost constant and the NaOH absorption is still increasing. This is in the region of the second flat in the absorption curve. When H_2O is replaced by MeOH, the cellulose system undergoes only a very slight modification which is not influenced by the addition of H_2O.

Text. Research J. Feb. 1949

Cellulose Structure

Stratification of loose places in the cellulose molecules of fibers. E. Husemann and A. Carnap. *Naturwissenschaften* **32,** 79–80 (1944) (through *Chem. Abstr.* **42,** 4341*e* (June 20, 1948)).

Investigation of the effects of hydrolysis and oxidation on cotton, wool and ramie shows that at distances of approximately 500 glucose residues there are weak links which are at least 1,000 times more rapidly broken than the normal β-glucosidic links. These are called "loose places." Electron microscope investigation of preparations of different degrees of polymerization and different velocities of breakdown shows that these loose places appear to be arranged regularly in planes perpendicular to the thread direction.

Text. Research J. Feb. 1949

Macromolecular compounds. CCC-XIX. Cellulose. 90. Submicroscopic structural elements of cellulose fibers. E. Husemann. *Cellulosechemie* **22,** 132–5 (1944); cf. *C.A.* **42,** 4341*e* (1948) (through *Chem. Abstr.* **42,** 4341*f* (June 20, 1948)).

An extension of previous work (cf. *C.A.* **41,** 3961*b*). Whereas carefully wet-milled cotton and regenerated cellulose fibers show no well-characterized submicroscopic portions, such fragments became visible in the electron microscope when cotton or ramie was hydrolyzed. Even when this hydrolysis was continued until the average D.P. was 80–180 (in the case of ramie) and 70–150 (in the case of cotton) and the product was obviously nonhomogeneous, by far the largest percentage of fibrillar fragments were about 2,250 Å. in length and surprisingly uniform. They correspond to about 450 glucose residues. This was shown by an extensive statistical study in which the fibrillar fragments were actually measured and counted and distribution curves were drawn in which the ordinates represented the % fibrillar fragments and the abscissas gave the fibrillar length. Sharp peaks invariably occur, corresponding to about 2,250 Å. In other unpublished distribution studies on a homopolymeric series of cotton celluloses, it was shown that the distributions found deviated widely from those calculated and that products in the range of 400–500 D.P. were very uniform. These findings were substantiated in the case of ramie heterogeneously hydrolyzed and homogeneously oxidized. Husemann's data are best explained by assuming that in the cellulose molecules not all the linkages are equally resistant to hydrolysis and that, at regular intervals of about 500 glucose units, weak spots occur which are far more rapidly hydrolyzed than are other linkages in the cellulose chain. In the light of these findings, the biosynthesis of cellulose is discussed briefly. Electron photomicrographs and graphs are included.

Text. Research J. Feb. 1949

The structure of natural and synthetic cellulose fibers. H. Staudinger, P. Herrbach, and H. Stock. *Makromol. Chem.* **1,** 60–9 (1947); cf. *C.A.* **37,** 527[2] (through *Chem. Abstr.* **42,** 5660*b* (Aug. 10, 1948)).

Artificial cellulose fibers of a high degree of polymerization (D.P.) were prepared to determine how much the length of the molecule influences the strength of the fiber. The tenacity and folding strength of viscose fibers of equal D.P. increased with an increasing concentration of the spinning solution. The folding strength was determined in the apparatus of Franz and Henning (*Melliand Textilber.*) **17**, 121 (1936). Fibers spun from 1.5–3% solutions had low strength in spite of high D.P. (1,000–1,500). It is concluded that, for the strength of viscose fibers, the length of the molecule is not of such decisive influence as has been assumed. The better properties of native fibers are attributed to the arrangement of the cellulose molecules in long spirals rather than to cross-linking or to the presence of a cementing substance. The special structure of the native fiber is destroyed in solution. This is shown by the difference in strength between native and regenerated fibers of cellulose nitrate. The folding strength of native fibers of cotton and ramie was increased by nitration, but the same cellulose nitrate dissolved in acetone and spun in water gave fibers of very low strength. Also, although the triacetates of native celluloses were scarcely soluble in *m*-cresol, the triacetates of celluloses regenerated from solution showed high solubility. Complete solubility was obtained only when the cellulose was precipitated from a dilute (1%) solution. Cellulose from flax was an exception in that regeneration did not appreciably affect the solubility of the triacetate in *m*-cresol. It is assumed, therefore, that still finer differences in structure exist between the celluloses of various plants.

Text. Research J. Feb. 1949

Cellulose Studies

Cellulose studies. X. Heterogeneous degradation of cellulose and viscose rayon in organic acid solutions. P. C. Mehta and Eugene Pacsu. TEXTILE RESEARCH JOURNAL **18**, 387–95 (July 1948). *Cf.* T.R.J. **15**, 354 (1945); **16**, 105, 163, 243, 318, 390, 490, 564 (1946); **17**, 405 (1947).

On the basis of their experiments, Pacsu and Hiller have shown that the classical concept of the structure of cellulose as built up from glucose anhydride residues connected by 1,4-β-glycosidic linkages is inadequate. They proposed that in cellulose there are units of about 260 glucose anhydride residues linked through 1,4-β-glycosidic bonds, these units being then connected by hemiacetal or acetal bonds. The present experiments on the kinetics of heterogeneous hydrolysis of cellulose in organic and inorganic acids were conducted to test the validity of this concept. The results are: (1) an initial rapid hydrolysis down to a D.P. of about 260; $k = 3.43 \times 10^{-3}$ at 97°C, which is of a much higher order than the rate constant for hydrolysis of the 1,4-β-glycosidic bonds under similar conditions; (2) a practically complete standstill of the hydrolysis after the limiting D.P. of 260 is reached; (3) a negative value for the entropy of activation as calculated from Eyring's equation for absolute reaction rates, in contrast to the positive value obtained for the random hydrolysis of cellulose, starch, maltose, etc. Similar experiments on commercial viscose rayon showed hydrolysis to be at a uniform rate down to a D.P. of about 60, after which no appreciable change occurred. Authors

Text. Research J. Feb. 1949

D. P.'s of Cellulose in Cotton

Degree of polymerization of cellulose in cotton fibers. Lyle E. Hessler, George V. Merola, and Earl E. Berkley. TEXTILE RESEARCH JOURNAL **18**, 628–34 (Oct. 1948).

Cotton fiber from unopened bolls gave values for degrees of polymerization (D.P.) of 5,940 for primary walls only and 10,650 for fibers with secondary thickening. The young fiber with primary walls only was more sensitive to degradation both when dried without treatment and when the moisture was replaced by organic solvents. The greatest cellulose breakdown occurred when the fiber was oven-dried at temperatures of 105°C and above. The fibers with secondary walls were more resistant to depolymerization associated with drying and were resistant to degradation at temperatures below 150°C. Degradation in solvents used to replace the water was greatest for the dioxane, which had the lowest boiling point, and was progressively less as the boiling points increased. The presence of traces of peroxides in the dioxane may have contributed to the degradation. The effect of weathering on cotton fiber is frequently pronounced, and certain types of degradation are associated with areas of high light intensity. The initial photochemical oxidation is rapid at first and gradually levels off after satisfying the more easily oxidizable bonds. A keir boil of 1 hr., which breaks damaged oxygen bonds, had no effect on the D.P. of fiber from unopened bolls that had not been exposed to light, but readily lowered the D.P. of field-exposed cotton. The data show two types of damage, one of which is evident immediately, the other after boiling in alkali. Cotton fiber exposed to sunlight for 90 days showed only slightly lower D.P.'s than fiber exposed for 43 days, which indicates that the rate of depolymerization is rapid at first and then decreases with time. The D.P.'s of the fibers from the major portions of the seeds were fairly uniform and relatively high, whereas those of the fibers from the chalazal caps, where a preponderance of thin-walled fibers are found, were significantly lower. Within the cotton boll the highest D.P.'s were at the bases of the locks, with a progressive decrease from base to tip. Authors

Text. Research J. Feb. 1949

Cellulose Acetate Preparation

Cellulose acetate. I. M. Goswami and P. K. Choudhury. *J. Indian Chem. Soc., Ind. & News Ed.* **9**, 114–23 (1946) (through *Chem. Abstr.* **42**, 4745*h* (July 10, 1948)).

In attempting modifications of the Miles' process for the preparation of

cellulose triacetate (Brit. Patent 1930 (1905)), it was found that the use of 15–18.4% H_2SO_4 caused degradation of the cellulose; the product was powdery and was insoluble in $CHCl_3$ and other solvents. With lower concentrations of catalyst (1.8–8%) and with effective control of the temperature, it was possible to obtain fibrous triacetates in 3–17 hrs. A consideration of other methods led to the idea that HCl, generated *in situ*, was the real catalyst. Therefore, H_2SO_4 was replaced by $POCl_3$. Satisfactory results were obtained under the following conditions: 10 g. cellulose, 50 cc. AcOH, 40 cc. Ac_2O, and 0.15 cc. $POCl_3$ at 99°C for 3.5 hrs.; 50 g. cellulose, 300 cc. AcOH, 150 cc. Ac_2O, 0.5 cc. $POCl_3$ at 120°C for 1.25 hr. Higher temperatures (120–34°C) adversely affected the cellulose. Details of a number of experiments are reported.

Text. Research J. Feb. 1949

Refractive Index of Cellulose Films

Refractive index of cellulose film. Saburo Okajima and Taneyasu Iwamoto. *J. Soc. Chem. Ind. Japan* **44**, 848–54 (1941); cf. *C.A.* **34**, 3155[3]. **IV. Refractive indexes of nitrocellulose film and nitrated ramie** (through *Chem. Abstr.* **42**, 2428e (Apr. 10, 1948)).

Films were formed of nitrocellulose of 11–14% N by pouring 3% solution in amyl acetate on a glass plate and evaporating off the solvent. Their refractive indexes $f\,||$ and $f\perp$, for plane-polarized light vibrating in parallel with and normal to the film surface, respectively, were measured. As the content of N increased, $f\,||$ decreased from 1.530 to 1.526, while $f\perp$ was about 1.524 and nearly constant. In nitrated natural and mercerized ramie the refractive indexes $n\,||$ and $n\perp$ parallel and normal, respectively, to the fiber axis were measured by Becke's method. In nitrated natural ramie, $n\,||$ decreased from 1.5305 to 1.5140 and $n\perp$ increased from 1.5160 to 1.5189 when the N content increased from 11.46 to 13.95%; $n\,||$ and $n\perp$ coincided near 13% N. In nitrated mercerized ramie, $n\,||$ and $n\perp$ had the same tendency of variation as above, but $n\,|| > n\perp$ for all N contents, and both values were always higher than those of nitrated natural ramie. **V. The type of change in refractive indexes by the plastic elongation of regenerated fiber and the effect thereon of varying the degree of swelling.** Nitrocellulose fiber was denitrated, and 3 groups of samples of anisotropic fiber were prepared: (1) air-dried and then stretched by supporting various weights, (2) immersed in 96% alcohol for 1 day and stretched immediately afterward, (3) stretched immediately after preparation in the wet state. Refractive indexes were determined as before. A linear relation exists between $n\,||$ and $n\perp$ of all samples. Change in $n\,||$ and $n\perp$ with elongation becomes greater as the degree of swelling of fiber diminishes, and the type of change in cases of air-dried and water-wetted fibers satisfies Kratky's deformation mechanisms (*C.A.* **33**, 3583[6]). No further change is observable on elongation over 1.6–1.7. The $n\,||$ and $n\perp$ of regenerated cellulose stored in a desiccator are constant for 30–40 days, but later increase gradually.

Text. Research J. Feb. 1949

Carboxymethylation of Cotton

The partial carboxymethylation of cotton to obtain swellable fibers, II. J. David Reid and George C. Daul. TEXTILE RESEARCH JOURNAL **18**, 551–6 (Sept. 1948); *cf.* T.R.J. **17**, 554–61 (1947).

The effect of the partial carboxymethylation of cotton has been studied on cloth treated in the piece and on cloth woven from treated yarn. The treatment of the cloth without tension yielded a product of satisfactory hand and feel with lower water permeability and greater air permeability than those of untreated material; cloth treated under tension had even greater air permeability but the water permeability was only slightly decreased. Cloth was successfully woven from treated plied yarn but the expected decrease in water permeability was not attained. It should be possible, with slightly increased carboxymethyl substitution and a tighter weave, to obtain a cloth whose yarns would swell enough to close all interstices. Nevertheless, this effect would be somewhat counterbalanced by the tendency of the cloth to become completely wet, allowing water to penetrate the fabric more readily. Treated cloth absorbs water two to three times as rapidly as untreated cloth, although the total amount of water taken up is only slightly greater than that taken up by a mercerized control. The drying rate is about the same. The dyeing characteristics of carboxymethylated cotton are changed greatly. The results indicate improvement of cotton for special uses where swellability or rapid absorption is desired. The addition of the carboxyl group may also serve as a starting point for additional chemical change in the characteristics of the cotton. Authors

Text. Research J. Feb. 1949

Substantivity of Dyes

Part IX—Ufimtzev's colored compounds; the steric hindrance of resonance and the development of hypsochromic character and non-substantivity; the anomaly of cis-azobenzene; and the substantivity of dyes from the 4:4′-diamino-*o*, *m*, and *p*-terphenyls; with notes on the substantivity of naphthol AS-G, and on the structures of the diazophenols and diazonaphthols. H. H. Hodgson. *J. Soc. Dyers and Colourists* **64**, 184–6 (May 1948).

The novel kind of intramolecular reaction assumed by Ufimtzev to explain the appearance of color in colorless compounds of the type $C_6H_5{-}NH{-}CH_2{-}C_6H_4{-}NO_2$ when the phenyl is replaced by the acenaphthenyl or fluorenyl group is shown to be unnecessary, since the ordinary classical theory will suffice if the Baker-Nathan effect (hyperconjugation) be operative. Steric hindrance of resonance and consequent lack of coplanarity in molecules can explain absence or only partial development of substantivity of dyes and also hypsochromic effects but the same hypothesis is shown to throw considerable doubt

on the validity of the alleged structure of cis-azobenzene, which is bathochromic compared with trans-azobenzene, contrary to the reasonable view that the more strained structure—*i.e.*, the cis—should be hypsochromic. The coplanar hypothesis is shown to provide an explanation of the substantivity of the dyes from the non-coplanar 4:4′-diamino-*o*-terphenyl. An explanation is also included for a previous overstatement by the author for the substantivity of naphthol AS-G, and brief reference is given to the recent confirmation by absorption spectra of the ionic quinonoid structures assumed by the present author for the colored diazophenols and diazonaphthols.

Text. Research J. Feb. 1949 Author

Mechanical Behavior of Fibers

A new concept of the mechanical behavior of fibers. Harris Burte, George Halsey, and J. H. Dillon. TEXTILE RESEARCH JOURNAL **18,** 449–69 (Aug. 1948); **18,** 635 (Oct. 1948).

Part I presents a review of the various theories of mechanical behavior or fibers. It is shown that the linear 3-element model gives a fairly good qualitative description of relaxation, creep, and stress-strain phenomena. With this linear model extended to give a distribution of relaxation times, the time scales of the relaxation and creep functions are expanded to ranges which approach those observed experimentally. However, the more complicated linear model is cumbersome, particularly when used to explain stress-strain data, and it does not yield the proper values of the elastic and viscous constants when the rate of strain is changed by a large factor. The 3-element model with Hookean springs and Eyring dashpot is discussed, and it is shown that it accomplishes the extension of the time scale for relaxation and creep, and also yields relationships involving changes in the rate of elongation of stress-strain experiments which agree quite well with data on acetate rayon. The usefulness of graphical methods of analysis of stress-strain curves is pointed out. For other fibers, the agreement with experiment is not so good. Efforts to generalize the Eyring model by considering the "energy barriers" to be asymmetric, employment of non-Hookean springs, and increasing the number of elements in the model have given better agreement of theory with experiment but leave much to be desired in the explanation of the behavior of wool fibers. The recently published theory of Burte and Halsey (*T.R.J.* **17,** 456 (1947)) is discussed in some detail in Part II. This new theory does not employ a dashpot-spring model but involves a concept of energy states, with populations changing as the fiber is extended. The reaction-rate techniques of Eyring are used to develop the mathematical formulas for relaxation, creep, and stress-strain behavior. The theory appears to explain qualitatively the phenomena of thixotropy and the final upward inflection of the stress strain curves for wool, nylon, and rubber. Preliminary experimental data on wet wool fibers are presented which appear to confirm quantitatively the new theory. Of particular interest is the "secondary yield point" observed for some wool fibers and predicted qualitatively by the theory. There are some difficulties in the application of the theory, and these are discussed. Authors

Text. Research J. Feb. 1949

Plasticity of Fibers

The creep behavior of textile fibers. M. T. O'Shaughnessy. *Phys. Rev.* **70,** 802 (1946). **An investigation of the load-deformation characteristics of Celanese and wool with particular reference to the use of these materials in carpet pile.** R. W. Work, A. M. Thorne, and M. R. Livingston. *Ibid.* 803. **Diffraction of visible radiation by cellulose acetate yarn.** Emmett Martin. *Ibid.* **71,** 488 (1947) (through *Chem. Abstr.* **42,** 4756g (July 10, 1948)).

The above are titles of papers presented before the Am. Phys. Soc. and published in abstract form.

Text. Research J. Feb. 1949

Plastic Flow and Deformation

Theory of plastic flow versus theory of plastic deformation. W. Prager. *J. Applied Phys.* **19,** 540–3 (June 1948).

Typical theories of plastic flow and plastic deformation are discussed, and the concept of neutral change of stress is introduced. A neutral change of stress may be considered as a limiting case of either loading or unloading. It therefore seems reasonable to demand that the stress-strain relations for both loading and unloading should predict the same change of strain when applied to a neutral change of stress. It is shown that this condition is satisfied by the theories of plastic flow but not by the theories of plastic deformation. Author

Text. Research J. Feb. 1949

Supercontraction of Keratin

The supercontraction of keratin fibers. XIX. E. Elöd and H. Zahn. *Melliand Textilber.* **28,** 2–4 (1947); cf. *C.A.* **40,** 6903[8]; *Melliand Textilber.* **27,** 68 (1946) (through *Chem. Abstr.* **42,** 5677g (Aug. 10, 1948)).

Horsehair was shrunk by various methods to give the supercontracted form described by Astbury (*C.A.* **28,** 3238[1]) and was found to give an x-ray pattern which does not correspond to Astbury's structure for this protein. Portions of fiber were treated in various media including: 5% $Na_2S_2O_5$, hot air, steam at 100°C, water at 130°C, formamide at 115°C, and thioglycolic acid at 35°C. The treatments required various lengths of time. Formamide gave fully shrunk fibers after only 10 min. All the samples prepared in various ways gave diffraction patterns which were distinguished from that of extended β-keratin only by diminished orientation and decreased sharpness. The shortening of the fiber and the observed changes in the x-ray pattern are considered to be due to two effects. The micelles which are originally orientated parallel to the fiber direction rotate to a position oblique to the fiber axis. Secondly,

the micelles, which are pictured as long, flat, boxlike structures, move various distances perpendicular to the chain, giving a wavy structure which is further shortened. Cf. *C.A.* **40**, 6093[8].

Text. Research J. Feb. 1949

Action of Phenols on Keratins

The action of phenolic compounds on fiber keratins. Helmut Zahn. *Z. Naturforsch.* **2b,** 286–91 (1947) (through *Chem. Abstr.* **42,** 5678*a* (Aug. 10, 1948)).

Treatment of sheep wool at 20°C with 1–7% aqueous phenol causes a reversible increase in the amount of stretch before breaking and a reduction of the elastic modulus. Heating horsehair in more concentrated solutions of phenol, pyrocatechol, resorcinol, hydroquinone, *o*- or *p*-nitrophenol, or salicylic acid causes an irreversible shortening of the fiber. The amount depends on the compound, its concentration, the temperature, the duration of heating, and the pH. X-ray patterns and decreases in swelling anisotropy and in double refraction show that molecular disorientation has occurred. Solubility in NaOH solution increases only slowly with duration of treatment; the digestibility by pancreatin greatly increases at once, showing the presence of disoriented keratin. Primary valences (peptide links and cystine bridges) are unaffected; these phenolic compounds break only H bonds. This is useful in studying separately the behavior of H bonds in keratins.

Text. Research J. Feb. 1949

Moisture Determination

Moisture determination in textiles by electrical meters: Part I. Richard K. Toner, Carol F. Bowen, and John C. Whitwell. TEXTILE RESEARCH JOURNAL **18,** 526–35 (Sept. 1948).

Results are reported from a study of two electrical moisture meters adaptable to bulk textile materials. Calibration curves at a single temperature are reported for white, scoured, wool yarns. Accuracy of the meters is dependent upon a calibration against an independent measurement of moisture. A modification of the loss-in-weight oven method was used as reference. Precision for both ovens and meters is based upon statistical analysis of groups of data. For instruments, in the best cases the value was approximately 0.25% with the ovens at 0.40% moisture, both figures based upon two-sigma limits, sampling variance having been removed. Authors

Text. Research J. Feb. 1949

Structure of Plant Tissue

Elasticity, plasticity and compression for cylindrical plant tissues and fine structure of their cell walls. Otto Trietel. *J. Colloid Sci.* **3,** 263–71 (June 1948).

The transverse modulus of compression for rubberlike elastic cylindrical plant tissues has the small value 0.1×10^9 g./cm.^{2}. Van der Waals forces between the chains of cellulose in the secondary cell walls of rubberlike elastic cylindrical plant tissues are small and are only dependent on distance. Elasticity, plasticity, and submicroscopic structure of average secondary cell walls in rubberlike elastic cylindrical plant tissues are closely related to each other because of the same elasticity-plasticity equation for these tissues $\frac{E}{\mu} \cdot \phi - m$. In this equation $m = 0.00002$ cm.^{2}/g., $\frac{E}{\mu}$ is the elastic ratio, and ϕ is the transverse coefficient of plasticity with respect to binding. Living cylindrical tissues of higher plants have stress-strain curves which are S-shaped on straight lines with a simple tail. In the secondary cell walls of these tissues crystalline and amorphous layers of cellulose alternate. Death of the plant occurs if the amount of the crystalline layers is too great. Dead metallic rods have stress-strain curves which are straight lines with complicated tails. These metals may have a crystalline lattice structure. Hence, it may be assumed that a large amount of crystallization in cylindrical plant tissue means death. The life conditions are related to the amorphous layers of cellulose in cell walls which have a molecular network structure. Authors

Text. Research J. Feb. 1949

Deformation of Polymers

Deformation and recrystallization in lattice-ordered high-polymer substances. Erwin Steurer. *Z. Naturforsch.* **2b,** 275–85 (1947) (through *Chem. Abstr.* **42,** 5660*e* (Aug. 10, 1948)).

Measurements of thermal expansion, x-ray patterns, double refraction, and heats of wetting of milled and unmilled preparations of cellulose, cellulose hydrate, methyl-, ethyl-, butyl-, and benzyl-celluloses, and Perlon T (nylon) show that mechanical energy distorts molecular chains. Addition of H_2O (or other liquids) or heating the substance to a "recrystallization temperature" region *t* restores the lattice structure, with an accompanying decrease of volume. The temperature *t* depends on intermolecular forces and becomes lower when the side chains on the cellulose molecule are made longer, or when H_2O or MeOH molecules enter intermolecular spaces. Above *t*, the chain units are mobile enough to re-form the lattice at once and no distortion is retained. About 1 kg.-cal. energy/mole is introduced into cellulose by milling, and 13–21% of the maximum possible disorder is developed.

Text. Research J. Feb. 1949

Polymer Structure and Mechanical Properties

An investigation of the relationship between polymer structure and mechanical properties. Part I. Relationship between structure, mechanical properties, and birefringence. Richard S. Stein and Arthur V. Tobolsky. TEXTILE RESEARCH JOURNAL **18,** 201–23 (Apr. 1948); **Part II. An experimental study of the stress and birefringence properties of several relaxing polymeric systems.** *Ibid.* 302–14 (May 1948).

Much progress in the understanding of the mechanical properties of high

polymeric substances has been made in the past few years. The theory of the mechanical properties of rubberlike systems has been developed by Guth, James, Gee, Treloar, and others; those of fiberlike materials have been studied by Mark, Harris, Eyring, Halsey, and others; and also, a theory for the double refraction of these materials has been developed by Kuhn and Treloar. In this paper some of these developments are critically reviewed and correlated by Stein and Tobolsky. The general problems involved in specifying the viscoelastic properties of a polymer are considered and the role of the prevailing theories within this framework is discussed. The application of the technique of simultaneous measurement of stress and birefringence for time-dependent behavior of these systems is considered. It is shown that through its use the mechanical behavior of complex systems may be resolved into more fundamental contributions. The method is applied in an experimental survey of the mechanical-optical properties of materials varying in nature from ideal rubbers to polycrystalline plastics. *Text. Research J. Feb. 1949* Authors

Structure of Rayon

Influence of fibrous structure of rayon on its swelling and density. II. Egon Elöd and H. G. Fröhlich. TEXTILE RESEARCH JOURNAL **18,** 487–9 (Aug. 1948).

Differences in the micro-structures of viscose rayon fibers, especially the differences between the outer and inner layers in fibers of one type, constitute the subject of this investigation. Layers are progressively removed by chemical action. The density and extent of swelling in water are measured before and after each removal. In this second paper of the series (*cf.* T.R.J. **16,** 432–7 (1946)) the method itself is explained in some detail, with a view toward a better insight into the proper interpretation of the results. Authors

Text. Research J. Feb. 1949

Iodination of Silk

Occurrence of new x-ray interferences by introduction of iodine into silk fibroin of the Bombyx mori type. H. Friedrich-Freksa, O. Kratky, and A. Sekora. *Naturwissenschaften* **32,** 78 (1944) (through *Chem. Abstr.* **42,** 4352*c* (June 20, 1948)).

When silk of the *Bombyx mori* type is treated with 0.1 *N*/I in KI, buffered with a secondary phosphate, and dried for 3 hrs. at 37°C, it is iodinated, and no longer gives Millon's reaction. An x-ray diagram of this iodinated silk shows a first-order reflection from the base plane (D = 7 Å.) which is comparable in intensity with the second-order reflection. More intense x-rays give very weak reflections within the first-order reflection. The period is 70 Å. It is probable that at distances of 70 Å. iodinated tyrosine molecules are included in the glycylalanine chain of the silk fibroin. Since an NH_2-acid residue has a length of 3.5 Å., it follows that each twentieth residue is tyrosine; this gives a tyrosine content of 10.5%, compared with one of 14% obtained by chemical analysis. The difference may be due to the fact that the x-ray diagram indicates crystalline tyrosine residues only, whereas chemical analysis includes possible amorphous tyrosine.

Text. Research J. Feb. 1949

Sodium Pectinate

Electrophoretic mobilities and fractionation of sodium pectinates. W. H. Ward, H. A. Swenson, and H. S. Owens. *J. Phys. & Colloid Chem.* **51,** 1137–43 (Sept. 1947).

The electrophoretic mobility of pectinate ions in buffered solutions at 0°C increases from near zero at 97% esterification to near 10×10^{-5} cm.^{2} sec.$^{-1}$ volt^{-1} at 0% esterification. The increase is not a simple inverse function of degree of esterification. Mobilities in buffer-free solutions calculated from values for limiting equivalent conductances vary from 31.1 to 44.7×10^{-5} cm.^{2} sec.$^{-1}$ volt^{-1} at 25°C as the equivalent weight is decreased from 720 to 191. Pectinic acids de-esterified *in situ* by citrus pectinesterase are more heterogeneous with respect to methoxyl content than those prepared with alkali *in vitro*. Enzymatically de-esterified pectinic acids were fractionated according to methoxyl content by means of sodium chloride, acid, or a combination of sodium chloride and acid. The data for the fractionation obtained with one sample showed that the majority of the material contained less methoxyl than the average percentage of methoxyl determined for the sample. *Text. Research J. Feb. 1949* Authors

Strength Relationships

Relation of specific strength of cotton fibers to fiber length and testing method. James N. Grant and Ora W. Morlier. TEXTILE RESEARCH JOURNAL **18,** 481–7 (Aug. 1948).

Four cottons in commercial production, covering a range of such physical properties as strength, length, and fineness, were studied in a comparison of two methods of determining fiber strength—the individual fiber test and the Pressley flat-bundle test. Because of the combing action in bundle preparation, cotton fibers broken in the flat-bundle test represent the longer fibers found in a sample of cotton. These remaining fibers are not representative of the length of the original sample; and since fiber specific strength increases with fiber length, neither are they representative of the strength of the original sample. This increase in specific strength with increase in length is evident whether fibers are broken individually or in aggregates. The relationship between the logarithm of individual fiber tensile strength and the logarithm of the specimen length used is inversely linear. The flat-bundle test represents the strength of fibers whose specimen lengths were deduced to be between $\frac{1}{16}$ and $\frac{3}{32}$ inch. Authors

Text. Research J. Feb. 1949

Viscoelastic Behavior

A new theory of non-linear viscous elasticity, II. The curve shape

factor. S. M. Katz and G. D. Halsey, Jr. TEXTILE RESEARCH JOURNAL **18,** 557–9 (Sept. 1948).

The 4-parameter equation of Burte and Halsey (Paper I; *T.R.J.* **17,** 465–76 (1947)) has been transformed to a single-parameter equation. The solutions of this equation were investigated and, in each case, the shapes of the curves varied so little with changes in the parameter that the viscous constants could not be calculated accurately by comparison of these curves with those obtained experimentally. The application of this single-parameter equation, therefore, was found to be impracticable. Authors

Text. Research J. Feb. 1949

Determination of Viscoelastic Properties

A theory of commercial yarn testing. Charles J. Geyer, Jr., C. H. Reichardt, and George Halsey. TEXTILE RESEARCH JOURNAL **18,** 338–50 (June 1948).

A method has been devised for the application of the theory of the 3-element shear model of Eyring and coworkers to textiles which does not necessitate the location of the "basic spring line" and thus is readily applicable to both yarn and fiber tests and to the commercial inclined-plane and pendulum-type testers. It is also applicable as a first approximation to those textiles which do not possess a "basic spring line" as such. The method employs the conventional spring constants or elastic moduli, but determination of the viscous constants involves the magnitude of the relaxation in constant-rate-of-elongation experiments (or the magnitude of the creep in constant-rate-of-loading experiments) from the upper envelope per interval of time. The relationship has been employed to establish the correlation between the viscoelastic properties of "slashed" and "unslashed" viscose tire-cord rayon yarns and also to show the identity of single-filament stress-strain relationships with those of yarns of normal twist of the same textile. The simplicity of technique which enables this method to be used as a routine laboratory test for the determination of the viscoelastic properties of textiles is an advantage over previous methods, which were often unsatisfactory from both a theoretical and an experimental viewpoint. Authors

Text. Research J. Feb. 1949

Visco-Elastic Properties of Wool Fibers

The visco-elastic properties of wool fibers. T. Peters and J. Speakman. TEXTILE RESEARCH JOURNAL **18,** 511–18 (Sept. 1948).

The shortcomings of existing theories of visco-elastic behavior, as applied to wool, are discussed. X-ray data indicate that in the crystalline regions of the fiber the polypeptide chains exist in the form of folded grids (α-keratin). On stretching the fiber, these are transformed to a less folded structure (β-keratin). The theory of absolute reaction rates is applied to this α-β transformation, and, assuming that the folded α-keratin structure exists in the amorphous as well as in the crystalline regions of the fiber, an expression for the equilibrium stress-strain curve is derived. The theory is applied to the mechanical properties of wool in 98% formic acid and in saturated air. The swelling pressure in formic acid is great enough to separate the folded grids from one another, and the mechanical behavior in this medium should be relatively simple. The stress-strain curve indicates that two phases, differing in ease of extension, exist in the unstressed fiber. The more easily extensible phase originally consists of 50% β-keratin, and probably exists in the more amorphous regions. In saturated air the elastic behavior is more complex, owing to pronounced creep effects. This difficulty is overcome by confining attention to the instantaneous extensions of a series of fibers under different stresses. H. Burte

Text. Research J. Feb. 1949

Wool-like Viscose

The viscose of Genitsu Kita and his collaborators. XCVI. Manufacture of wool-like kinky artificial fiber of high tensile strength. T. Suda. *J. Soc. Chem. Ind. Japan* **45,** 778–82 (1942) (through *Chem. Abstr.* **42,** 6531g (Sept. 10, 1948)).

In order to make wool-like artificial fiber excellent in kinkiness, tensile strength, and extension, the following conditions are required: viscose is 6.5% alkali and 7.7% cellulose; viscosity of viscose is about 50 sec. by the falling-sphere viscometer; the degree of seasoning of viscose is 11–15 H.Z.; a coagulating bath of 110–20 g. H_2SO_4, 350 g. Na_2SO_4, and 15–20 g. $ZnSO_4$ per liter; a fixing solution of 50–100 g. H_2SO_4 and a little Na_2SO_4 per liter; temperature over 85°C; the extension of fiber in the fixing bath about 40%. **XCVII. Properties of wool-like kinky artificial fiber of high tensile strength.** *Ibid.* 782–5. Test results are as follows: (1) The kinkiness of this artificial fiber is permanent, steady, and similar to that of Merino wool. (2) Tensile strength in dry and wet condition is greater than that of the fiber as usually prepared. Elongation at the breaking point is about 20%. (3) The elasticity of this fiber is greater than that of the fiber as usually formed. (4) Spinning property is very good. It can be used not only in wool spinning, but also in silk and in cotton spinning. (5) Heat retention of this fiber is better than that of silk wadding.

Text. Research J. Feb. 1949

Copper and Xanthate Viscosities

Effect of drying pulps on the viscosities of their solutions. K. Lauer, L. Skark, and A. Kobiljanski. *Cellulosechemie* **22,** 136–7 (1944) (through *Chem. Abstr.* **42,** 4346*a* (June 20, 1948)).

Even in carefully performed molecular-weight determinations on an individual pulp sample, some of the results diverged so widely that they no longer fell within the usual experimental error of the determination. Apparently the variations were due to differences in drying. Hence, the effects of various drying methods on the Cu and xanthate viscosities were studied.

Text. Research J. Feb. 1949

BLEACHING: DYEING: FINISHING

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Acid Dyes

A method for the graphical representation of the dyeing properties of acid wool dyes. H. Ris, W. Stocker, and E. W. Thommen. *J. Soc. Dyers and Colourists* **64**, 297–304 (Sept. 1948).

In order to provide the dyer with detailed information on the properties of individual wool dyes, a method of graphical representation has been developed. One set of graphs obtained from dyeings illustrates exhaustion rates with varying pH values with a constant temperature and time cycle. Another set shows the "migrating power" of the dye, and a third set can be used to show the rate of exhaustion of a shading addition. Examples are given of the use of the graphs in practical dyeing formulas.

J. A. Woodruff

Text. Research J. Feb. 1949

Chrome Dyes

Re-utilization of the chromium present in wool fabrics dyed with chrome dyes as a mordant used in the additive dyeing of the regenerants. J. B. Puig. *Ion* **8**, 149–56 (1948) (through *Chem. Abstr.* **42**, 6120*b* (Aug. 20, 1948)).

The methods and advantages of treating dyes of the alizarin type with chromium are discussed.

Text. Research J. Feb. 1949

Dye Solutions

Influence of permeation reagent on the permeation of dye solutions. S. Ueno. *J. Soc. Chem. Ind. Japan* **47**, 151–5 (1944) (through *Chem. Abstr.* **42**, 6119*g* (Aug. 20, 1948)).

Aqueous solutions of dyes have the greatest penetrating power for filter paper. Next in order are aqueous solutions treated with Gardinol, oleic alcohol, and cetyl alcohol sulfates. Sodium oleate has the greatest retarding effect. In permeation, water and dyestuff separate. The permeation velocity of water is uniform but that of the dyestuff is uneven.

Text. Research J. Feb. 1949

Hosiery Dyeing

Hosiery dyeing. H. Unwin. *J. Soc. Dyers and Colourists* **64**, 245–48 (July 1948).

A practical discussion of dye-bags, dyeing machines, and methods of dyeing viscose, acetate, cotton, nylon, and silk alone or in appropriate mixtures in hosiery.

J. A. Woodruff

Text. Research J. Feb. 1949

Package Dyeing

Automatic control essential in package dyeing. C. E. Bowden, Jr. *Instrumentation* **3**, No. 3, 27–8 (1948) (through *Chem. Abstr.* **42**, 6119*i* (Aug. 20, 1948)).

Package dyeing, an automatic control system, and the flexibility of the control system are discussed.

Text. Research J. Feb. 1949

Electrical Theory of Dyeing

The electrical theory of dyeing. W. Harrison. *J. Soc. Dyers and Colourists* **64**, 248–52 (July 1948).

The theoretical ideas of Neale and Crank are criticized, and their estimates of the specific surface of cellulose are shown to be too high. The surface of contact between water and cellulose is regarded as an electrical condenser, the water possessing a positive charge and the cellulose a negative charge. An estimate, based on the contact potential, of the number of hydroxyl groups per unit surface of the cellulose corresponds with that to be expected from molecular models. The author's theory of the aggregation of direct dyes in the pores of cellulose is supported by experimental work on the dyeing of stretched and unstretched fibers in the presence of increasing concentrations of Sapamine P, and it is shown that such aggregation may be accounted for by hydrogen-bond formation.

Author

Text. Research J. Feb. 1949

Dyeing, Past and Present

Dyeing, past and present. F. Tripp. *Textile Bulletin* **74**, 110, 112, 115 (Sept. 1948).

Part II of a series dealing with the development of dyeing agents. Synthetic dyes, direct dyes, and sulfur dyes are described and their methods of application are discussed.

A. L. Landau

Text. Research J. Feb. 1949

Dyeing and Finishing

Dyeing and finishing from the consumer angle. R. L. Elliott. *J. Soc. Dyers and Colourists* **64**, 179–83 (May 1948).

The effect of the rationing of textile materials to the consumer and of the regulations of the Board of Trade Utility is said to be shown in the greater consumer consciousness of quality of merchandise, especially with respect to length of satisfactory performance of the garment. This condition has aided in the demand for satisfactory finishes which stabilize the fabrics or otherwise increase their periods of usefulness. Changes in the consumer's methods of laundering materials—for instance, the use of hypochlorite in the home—are showing up faults not only in the sulfur-dyed materials but also in the blue vat-dyed materials when overoxidation of amine groups in Blue RC or Blue GCD occurs. The need for attention to details of knitting and construction of knit wool materials as well as the degree of shrinkage-control treatments is given considerable discussion. In general, the application of shrink-resist processes to civilian goods has not been overwhelmingly successful. Constructive comments are also offered on light, washing, and perspiration fastness.

J. A. Woodruff

Text. Research J. Feb.1949

The Hydrosulfites

The hydrosulphites—production, properties, and textile applications. G. Brearley and J. Starkie. *J. Soc. Dyers and Colourists* **64**, 278–83 (Aug. 1948).

A review of the methods of producing commercial hydrosulfites and

sulfoxylates, an outline of their properties, and a detailed description of some of the variations of the usual methods of application designed to deal with special textile problems. Physical methods of analysis are discussed. J. A. Woodruff
Text. Research J. Feb. 1949

Block and Screen Printing

Block and screen printing. P. Chadwick and E. S. Beton. *J. Soc. Dyers and Colourists* **64**, 274–8 (Aug. 1948).

These two methods of printing are treated separately. Histories of their developments and reviews of present-day practices are given.
J. A. Woodruff
Text. Research J. Feb. 1949

Textile Printing

Textile printing. F. Farrington. *J. Soc. Dyers and Colourists* **64**, 269–74 (Aug. 1948).

A full, practical discussion of the development of printing and of present-day application procedures. The influence of John Mercer upon the development of printing is emphasized. J. A. Woodruff
Text. Research J. Feb. 1949

Softening Agents

The principles of the textile-softening process. G. Nitschke. *Melliand Textilber.* **28**, 61–2 (1947) (through *Chem. Abstr.* **42**, 6542*c* (Sept. 10, 1948)).

A discussion of the use of various softening agents used in the spinning of wool and staple fiber.
Text. Research J. Feb. 1949

Slashing

Slashers and slashing. A. E. Silcox. *Textile Age* **12**, 62–4, 66, 68 (Oct. 1948).

Attachments, such as a second headway, which may be added to the head end of the slasher for increased production are discussed. A description is given of the instruments used for the control of size level and temperature in the size box, cylinder temperature, and moisture control. A. L. Landau
Text. Research J. Feb. 1949

FIBERS: YARNS: FABRICS: MECHANICAL PROCESSES

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Art and the Textile Industry

The Mather Lecture. Art in relation to the textile industry. A. Walton. *J. Text. Inst.* **39**, P220–8 (July 1948).

A historical review of the artist's influence in textiles from the age of the craftsman to the present day.
Text. Research J. Feb. 1949 L. A. Fiori

Design and Color in Textiles

Design and colour in textiles. P. Whiston. *J. Text. Inst.* **39**, P193–9 (June 1948).

An historical survey (from 3000 years ago in Egypt) of woven and embroidered fabrics, textile printing techniques, and textile design and colour artistry. L. A. Fiori
Text. Research J. Feb. 1949

Card Flatcleaner

Improved flatcleaner for cards. Anon. *Text. Mercury and Argus* **119**, 573, 575 (Oct. 22, 1948).

The new "Adelphi" flatcleaner, consisting of a wire fillet in place of the ordinary revolving brush and also having a brush which follows through the wire teeth of the flats, is described and illustrated. In operation the wire fillet of the cleaner penetrates the flat wire, resulting in many advantages over the ordinary method. L. A. Fiori
Text. Research J. Feb. 1949

Card Clothing

Respect your card clothing. G. T. Hunt. *Textile Inds.* **112**, 123–6 (Sept. 1948).

A discussion of card clothing regarding the number of the wire, the foundation construction, clothing the card, and the attention that should be given to the clothing after installation. Generally, the card clothing used will be No. 100 wire on the cylinder and No. 110 on the doffer and flats, the number of the wire being increased for fine work and decreased for high production on coarse work. The proper manner in which to cloth a card is described. A. L. Landau
Text. Research J. Feb. 1949

Comber Guard

The Bunting locking motion for guarding comber needle cylinders. Anon. *Text. Mercury and Argus* **119**, 491, 493 (Oct. 8, 1948) and *Textile Weekly* **42**, 896, 898 (Oct. 22, 1948).

A guard attachment for the protection of comber needle cylinders is described. L. A. Fiori
Text. Research J. Feb. 1949

Productivity in Cotton Mills

Variations in productivity between cotton spinning mills. P. D. Vincent. *J. Text. Inst.* **39**, P407–14 (Aug. 1948).

An analysis of the productivity of operatives. The first part of the analysis consists of the calculation of total O.H.P. (operative hours per 100 lb. of yarn). The second part consists of an examination of the causes of variation between mills and a relating of these to changes in technical conditions. A result of this study has been the assessment of the operator's performance in terms of an equation. Most of the analysis has been applied only to the cardroom. L. A. Fiori
Text. Research J. Feb. 1949

Cotton Varieties

Cotton varieties. P. M. Thomas. *Textile World* **98**, 107–22 (Oct. 1948).

A survey of fiber properties and outside factors affecting the character of cotton. Tables give details of fiber performance and suitability of different varieties of cotton.
A. L. Landau
Text. Research J. Feb. 1949

Designing of Fabrics

The designing of fabrics to meet consumers' requirements. W. E. Morton. *J. Text. Inst.* **39**, P187–92 (June 1948).

A consideration of the ways and means by which the designer can provide three of the main functional

features of fabrics—namely, dimensional stability, wearing properties, and draping properties. L. A. Fiori
Text. Research J. Feb. 1949

Coated Rayon Fabric

Coated rayon fabric. IV. Kehren. *Melliand Textilber.* **28**, 99–102 (1947). *Cf.* TEXTILE RESEARCH JOURNAL **17**, 461 (1947) (through *Chem. Abstr.* **42**, 6542*b* (Sept. 10, 1948)).

Rayon fabrics were coated with waterproof materials and subjected to various physical and chemical tests. The results are reported and discussed.
Text. Research J. Feb. 1949

Fiber Identification

Fiber identification. N. Willat. *Textile Age* **12**, 78, 80–2, 84–8 (Oct. 1948).

A review of the visual and chemical tests that are of value in identifying fibers. The ignition test, twist test, stain tests, and chemical solubility tests are outlined. A. L. Landau
Text. Research J. Feb. 1949

New Fiber Applications

Some commercial applications of the newer textile fibers. A. Johnson. *J. Text. Inst.* **39**, P309–17 (July 1948).

By mixing nylon with wool on both the "draft against twist" and "roller drafting" systems, yarn production nearly doubles and certain properties of woven and knitted fabrics are improved. Both the "core" and ordinary (doubling) methods of combining wool and nylon are considered and exemplified by yarn and fabric construction data. Particular emphasis is placed on the influence of denier and amount and direction of twist on the physical properties of resultant yarns and fabrics. Advantages cited for this combination of fibers are: (1) the combined yarns can be woven in fine counts without the necessity of sizing and are ideal for automatic looms, (2) the yarn lends itself to the production of light-weight, tightly woven, durable fabric for shirtings, or loosely constructed, yet strong and full in handling dress material, and (3) in knitted structures nylon/wool yarn produces strong, fine-gage socks and can be used with advantage for many other purposes; e.g., splicing thread. However, there are limitations in the forms the core twist can take and in the complications due to the processing of threads so dissimilar in size. Applicable to cotton, silk, and rayon fibers as well as to wool.
Text. Research J. Feb. 1949 L. A. Fiori

Viscose and the New Fibers

The outlook for viscose rayon in competition with the new synthetic textile fibers. N. Gralén. *Svensk Papperstidn.* **51**, 1–8 (1948) (through *Chem. Abstr.* **42**, 6533*g* (Sept. 10, 1948)).

After the discovery and development of the viscose rayon process is briefly traced, the structural molecular requirements for fibrous materials are discussed, with schematic illustrations for wool, natural silk, and nylon. An outline is given of the processes developed for producing fibers from large, already polymerized raw materials—namely, cellulose, alginates, and proteins, as well as through polymerization of synthesized compounds of low molecular weight. The properties of these various fibers are discussed and their chemical resistance and dyeing characteristics are given. Viscose rayon fiber has a good chance of maintaining its dominating position, even though newer artificial fibers will find extensive use for purposes where their properties are specifically suitable.
Text. Research J. Feb. 1949

Nylon Processing

Processing nylon staple on the cotton system. R. D. Bennet. *Can. Text. J.* **65**, 42–4, 46 (Aug. 20, 1948).

Speeds, settings, machine sequences for opening, picking, carding, and roving, and spinning operations are discussed. New data are presented.
L. A. Fiori
Text. Research J. Feb. 1949

Processing Problems of Nylon

Practical problems of processing nylon yarns. Anon. *Silk and Rayon* **22**, 1420, 1422 (Oct. 1948).

Some practical difficulties encountered in the spinning, twisting, warping, and weaving of nylon are examined. Notes on some of the most suitable types of nylon-wool mixture yarns for light-weight fabrics are given. L. A. Fiori
Text. Research J. Feb. 1949

Nylon on the Bradford System

Processing nylon staple on the Bradford worsted system. *Can. Text. J.* **65**, 46, 48, 52 (Sept. 17, 1948).

Operational data on the production of nylon and nylon-wool blends by the Bradford worsted system of spinning are given. Main points considered in detail are blending, dyeing and oiling, machine sequences and settings, drafts, and the "top" used in blending.
Text. Research J. Feb. 1949 L. A. Fiori

Nylon's Application to Textiles

Characteristics of nylon in its application to textiles. Anon. *Text. J. Australia* **23**, 444–6 (Aug. 20, 1948).

In fairly general terms, nylon's application in textiles with respect to (1) sewing threads, (2) knitted fabrics, and (3) finishing of fabrics is discussed. Such physical characteristics as smoothness, diameter uniformity, flexibility, freedom from kinking, strength, and extensibility are considered.* L. A. Fiori
Text. Research J. Feb. 1949

Oiling Rayon Staple

Oiling of rayon staple. Anon. *Textile Weekly* **42**, 634, 636 (Sept. 17, 1948).

The majority of rayon staple processing difficulties may be overcome by the application of suitable oil

* A note was made at the end of this discussion giving credit to *The Hosiery Trade Journal* for the reproduction.

emulsions (the ratio of water to oil being 3 to 1) at appropriate points. Advantages are discussed.

Text. Research J. Feb. 1949 L. A. Fiori

Soybean Fiber

Artificial fibers from soybean protein. S. Araki, K. Tarumi, and K. Iguchi. *J. Soc. Chem. Ind. Japan* **49**, 33 (1946) (through *Chem. Abstr.* **42**, 6120*d* (Aug. 20, 1948)).

Artificial fibers were prepared from soybean proteins obtained by alcoholysis and by a method which especially avoided a change in the nature of the protein, and the results were compared. Protein prepared from the extracted soybean by alcoholysis gave a sol of low index of refraction when dispersed in NaOH solution, and thus made it possible to prepare a highly concentrated spinning solution. The high coagulability made possible high-speed spinning in a bath of low temperature and low concentration and spinning with stretching. Treatment with formalin was rapid, and was effective on the stretched fiber.

Text. Research J. Feb. 1949

New Synthetic

DuPont announces new synthetic—Orlon. Anon. *Textile World* **98**, 102a–b (Sept. 1948).

Orlon, formerly called "Fiber A," is an acrylic yarn having properties placing it between nylon and rayon. Yarn sizes from 30–600 den. have been produced, with filament range of 1–5 den. Standard machinery may be used to process the fiber. Orlon corresponds to acetate in that it is difficult to dye. The properties of Orlon are listed, showing that the fiber has a specific gravity of 1.17 and a regain of 0.9–2% at 60% relative humidity. A. L. Landau

Text. Research J. Feb. 1949

Measuring Wool Staple Length

A note on the interpretation of Merino staple-length measurements. W. R. Lang and A. M. Chaudhri. *J. Text. Inst.* **39**, T249–52 (July 1948).

In assessing fleece length in the full, it is common practice with Merino staples to measure the straight staple length. It is shown in this discussion that length bears an approximately constant ratio both to mean fiber length and to the crimped length of the staple. This is considered to be a justification of the practice. Authors

Text. Research J. Feb. 1949

Removing Vegetable Matter and Paint from Wool

Methods of depitching wool and removing vegetable matter without carbonizing. Monefred T. Hoffman. *Can. Text. J.* **65**, 40–2 (Oct. 1, 1948).

A new method of wool scouring removes grease, paint, and tar simultaneously. Another method eliminates the vegetable matter contained in wool. Pilot-scale machines, processes, and principles are described. L. A. Fiori

Text. Research J. Feb. 1949

Fiber Drafting

Fibre movement in drafting. D. R. Cox. *J. Text. Inst.* **39**, P230–40 (July 1948).

Following a brief discussion of drafting principles, a mathematical conception is given of one aim of a theory of drafting—the correlation of the changes of variability of thickness that take place in drafting with the physical properties of the drafting machine and the sliver drafted. Equations are derived and their consequences are explained.

Text. Research J. Feb. 1949 L. A. Fiori

Effect of Draft Distribution

Effect of draft distribution. L. A. Fiori. *Textile Inds.* **112**, 92–7 (June 1948).

Report of studies on the effect of draft distribution of drawing, roving, and spinning processes with relation to the yarn strength and appearance. All tests were made in spinning a cotton yarn of 15.75 counts, varying the drafts at each stage of processing. Results show that draft changes in the drawing and roving did not create marked influence in the yarn strength whereas appreciable increase in spinning draft caused definite strength reduction. All details of testing are given. A. L. Landau

Text. Research J. Feb. 1949

Full-Fashioned Equipment

Full-fashioned equipment. F. K. Fogleman. *Textile Inds.* **112**, 251, 253, 255, 257, 259 (July 1948).

A review of the changes in full-fashioned knitting machinery which have taken place during the last half century. During this time the machine has been redesigned from a 16-section, 33-gage belt driven at 40 courses/min., to a 3-section, 50-gage unit operating at a speed of from 12 to 82 courses/min. and driven by an electronic drive. A table showing yearly improvements is included. A. L. Landau

Text. Research J. Feb. 1949

Lap Spindle

New lap spindle reduces work load. Anon. *Platts Bulletin* **6**, 32–3 (Mar.–Apr. 1948).

A new lap spindle for sliver and ribbon lap machines made from high grade steel tubing and including an aluminum hand wheel is introduced. Prolonged tests under mill conditions have proved this new spindle to be satisfactory. Work required in doffing is reduced. L. A. Fiori

Text. Research J. Feb. 1949

Modern Opening Line

The modern opening line. R. Z. Walker. *Textile Bulletin* **74**, 138, 140, 142, 144 (May 1948).

The operation and component assemblies of the feed table and vertical opener are described.

A. L. Landau

Text. Research J. Feb. 1949

Picker Models

Mill of today—pickers. R. Z. Walker. *Textile Bulletin* **74**, 86, 88, 90 (Sept. 1948).

The one-process picker has replaced multiple picking without a resulting deterioration in the quality of the lap. This change has been made possible to a large extent by the

numerous improvements in the machinery used in the opening line. Types of trash and the proper place to remove trash from the stock are discussed, particularly with respect to the ability of the card as a cleaning agent. A. L. Landau
Text. Research J. Feb. 1949

Short-Process Systems

Short process in the card room. F. Charnley. *Textile Weekly* **41**, 676, 678, 680, 682 (Apr. 9, 1948).

A brief review is given of the short-process methods in the card room: omission of roving, the 2-zone speed frame, and "fine-sliver" system. In most short process systems at least one doubling is discarded. It must therefore be anticipated that count variation will increase. The system most suitable for the class of yarn desired is pointed out. Suggestions for conversion of the mule spinning frame to suitable long-draft systems are also considered.
Text. Research J. Feb. 1949 L. A. Fiori

Roll Temperature Measurement

A new system of roll temperature measurement. J. D. Abbott. *Textile Inds.* **112**, 78–81 (Aug. 1948).

A general description, principle of operation, mechanics of operation, and the development of an instrument designed to measure the temperature of a revolving roll. The sensitive element consists of a coil of selected resistance which assumes the temperature of the roll and transmits this measurement to a Dynalog recorder. A. L. Landau
Text. Research J. Feb. 1949

Spinning Calculations

Spinning calculations simplified. Part III. Anon. *Platts Bulletin* **6**, 24–31 (Mar.–Apr., 1948); cf. TEXTILE RESEARCH JOURNAL **18**, 256 (Apr. 1948).

Charts numbered 1–18 of this series were given in *Platts Bulletin* **5**, 179–93 (Sept.–Oct. 1947) and 209–18 (Nov.–Dec. 1947). Charts numbered 19–24 are given in this report. Pounds per hr. for the picker with 8, 9, and 10-in. double pulleys can be found by using graphs numbered 19, 20, and 21 respectively. Graph 22 indicates the time required to make picker laps of various lengths and charts 23 and 24 give productions of card machines for various doffer speeds and sliver weights (in hanks) when using a 27-in. (27.72 in. over the wire) and 26-in. (26.75 in. over the wire) diameter doffers. L. A. Fiori
Text. Research J. Feb. 1949

Spinning calculations simplified. Part IV. Anon. *Platts Bulletin* **6**, 49–59 (May–June 1948).

This report describes charts numbered 25–32, from which may be obtained: drafts obtainable on a sliver lap machine having $1\frac{1}{4}$ in. front and back fluted rollers with a full range of draft gears; weights of lap for a sliver lap with a 16, 18, and 20 ends up and drafts ranging from 1.5 to 2.0; draft gears required for various total drafts on the ribbon lap machine together with the resulting drafts between fluted rollers; apparent draft on a comber for a given actual draft and waste extraction; draft change gear required to obtain actual draft on a new model Nasmith comber when using any of the various combinations of feed and cross-shaft gears; and the relationship between the weight of the laps fed to the comber and the weight of the sliver produced for a given apparent draft. In this last instance the hank of the sliver is also shown. L. A. Fiori
Text. Research J. Feb. 1949

Centrifugal Spinning System

P.S.C. system on short-fibred materials. Anon. *Textile Recorder* **66**, 70–1 (Oct. 1948).

The possibilities of the P.S.C. (centrifugal) system in the worsted field are being explored, but no data are available to indicate performance of this system for raw materials of cotton spinners. This discussion covers several practical points worth considering in this connection.
Text. Research J. Feb. 1949 L. A. Fiori

Centrifugal Spinning of Worsted

Centrifugal spinning of worsted. Anon. *Am. Wool and Cotton Reptr.* **53**, 13–14 (Sept. 30, 1948).

A centrifugal system of roving, spinning, and twisting is claimed to achieve higher production through large packages, less end breakage, and higher spindle speeds. The absence of balloon and bobbin drag makes possible spinning with less twist. A. L. Landau
Text. Research J Feb. 1949

Worsted Spinning

Worsted spinning. R. S. Audley. *Fibres* **9**, 357–9 (Sept. 1948).

Relevant points in establishing piece rates in worsted spinning are given.
Text. Research J. Feb. 1949 L. A. Fiori

Pin Control in Worsted Spinning

Pin control in worsted spinning. Anon. *Am. Wool and Cotton Reptr.* **26**, 75, 77, 79, 97, 98 (June 24, 1948).

A review of the mechanical features of the Warner-Swasey pin drafter and a discussion of the advantages accruing from its use in connection with the Bradford, French, and American systems of worsted spinning. Fiber lengths which may be processed range from $2\frac{1}{2}$ to 22 in. A. L. Landau
Text. Research J. Feb. 1949

Wool Spinning

Ring spinning for wool. Anon. *Platts Bulletin* **6**, 13–5 (Jan.–Feb. 1948).

The success of ring-spun woolen yarns is attributed to a twister tube. This apparatus inserts predetermined false twist to the sliver as it is drafted between feed and delivery rollers and also agitates the sliver. As a result a soft feel and full appearance are imparted to the yarn. Technical details for efficient operation and a brief history of the improvements associated with this mechanism are given. L. A. Fiori
Text. Research J. Feb. 1949

Mule Spinning

An end to mule oil splashing. Anon. *Textile Weekly* **42**, 752, 754 (Oct. 1, 1948).

A new bolster applied to mule spinning frames which requires oiling only once a month is described.

Text. Research J. Feb. 1949 L. A. Fiori

Variable Speed Ring Spinning

The case for variable speed ring spinning. R. Porter and J. D. Stanesby. *J. Text. Inst.* **39**, P397–406 (Aug. 1948).

A consideration of the effect of variable-speed spinning on end breakage and the consequent benefits derived therefrom. Installation of variable-speed ring spinning motors can be justified on the grounds of improved O.H.P. (operative hours per 100 lb. of yarn) with the further benefit of driving the ring frame at a speed most suitable for the particular yarn being spun. 7 tables of data. L. A. Fiori

Text. Research J. Feb. 1949

Variable Speed Spinning

Variable speed spinning of wool on a ring spinning frame. F. Puch and G. McK. Allcock. *New Zealand J. Sci. and Technol.* **29**, 52–75 (Sept. 1948).

Results for and methods used in making extensive tests in an investigation to determine the practical value of variable speed spinning on woolen ring spinning frames. If correctly adjusted, it is claimed, variable speed spinning yields an approximate over-all increase in production of 15%, with improved yarn and less maintenance. The forces and tensions existing upon the yarn as it is spun are analyzed. Tension is highest when winding is done on a small diameter. In order to maintain a constant tension it is necessary to have two superimposed speed variations in the drive—one to allow for the increase in the diameter of the bobbin as it fills up and the other to compensate for the changes in diameter during each traverse as the yarn is wound upon the tapered filled portion of the bobbin. Spindle speeds were recorded by means of a tachometer mounted directly on a spindle. Variations in yarn tension were determined through plots of full-sized photographs of yarn balloons. The centrifugal force of the yarn forming the balloon, the centrifugal force of the traveler, and, therefore, the friction of the traveler, are proportional to the square of the speed. As all tensions are in equilibrium with these forces, the tensions vary as the squares of the speeds. Speed calculations and charts are reproduced.

A. L. Landau

Text. Research J. Feb. 1949

Static Eliminator

The Shirley static eliminator. Anon. *Textile Weekly* **42**, 782, 784 (Oct. 8, 1948).

Static is cured by ionizing the air around charged fibers or yarns. Main advantages of this device are an effective range of 6–24 in. and provision enabling one power unit to serve electrodes on a number of machines. L. A. Fiori

Text. Research J. Feb. 1949

Twisting Machine

Platt's ring doubling frame. Anon. *Textile Weekly* **42**, 838–40 (Oct. 15, 1948).

A standard-type, ring doubling-frame embodying several outstanding mechanical features is discussed.

Text. Research J. Feb. 1949 L. A. Fiori

Automatic Weft Straightener

New automatic weft straightener cuts costs and improves fabric quality. G. Ransom. *Textile Age* **12**, 24, 28, 32 (Aug. 1948).

An explanation of the new automatic weft-straightening device actuated by means of reflected light and photoelectric cells. Use of the machine is claimed to result in reduced "seconds," higher production, savings in labor, and general improvement of quality.

A. L. Landau

Text. Research J. Feb. 1949

Automatic Yarn Testing

Automatic yarn testing. Anon. *Textile Weekly* **42**, 970 (Oct. 29, 1948).

A new testing machine (the "Autodinamografo") which tests all types of textile yarns provides a diagram on which are calculated the mean yarn strength and the elongation at break, and which shows maximum and minimum breaking points over a series of tests. L. A. Fiori

Text. Research J. Feb. 1949

Quality Control Charts

Quality control charts aid carding and spinning. A. D. Anthony and R. H. Souther. *Textile World* **98**, 111–3 (Mar. 1948).

Closer control of the variations existing in each process in the carding and spinning rooms aids in maintaining high standards of quality. The method of determining the allowable limits of variation is explained. Machine adjustments and tests are necessary only when the daily data sheets show that the variation has exceeded the established limits. A. L. Landau

Text. Research J. Feb. 1949

Woolen Condensers

Woolen condensers. Anon. *Platts Bulletin* **6**, 6–9 (Jan.–Feb. 1948).

This discussion deals with the merits of the ring doffer condensing apparatus and the tape condenser. Also described is a traversing condenser creel in which the thread guides are stationary and the surface drums traverse. This arrangement, especially developed to work in combination with the new-type large package spinning frames, allows a wide cheese to be wound on the condenser bobbin. L. A. Fiori

Text. Research J. Feb. 1949

MISCELLANEOUS

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Spinning Casein

The stability and filterability of spinning solutions of rennet casein. W. Winkler. *Kunstseide u. Zellwolle* **26**, 66–9 (1948)

(through *Chem. Abstr.* **42**, 6120c (Aug. 20, 1948)).

By the addition of certain chemicals, particularly a mixture of $Na_2S \cdot 9H_2O$ and $(COOH)_2 \cdot 2H_2O$, alkaline solutions of rennet casein may be stabilized for 48 hrs. or longer with respect to increase in viscosity on ageing. They can thus be filtered and utilized for spinning into fibers on the same basis as the solutions of textile or acid casein.

Text. Research J. Feb. 1949

Cellulose

Cellulose among the macromolecular substances. P. H. Hermans. *Plastica* (Holland) **1**, 9–18 (1948) (through *Chem. Abstr.* **42**, 6529g (Sept. 10, 1948)).

The physical properties of cellulose and other substances of high molecular weight are discussed, especially with reference to intermolecular cohesion and crystallinity.

Text. Research J. Feb. 1949

Mechanized Cotton Production

Mechanized production of cotton in Texas. H. P. Smith and D. L. Jones. Bulletin 704, Texas Agricultural Experiment Station. College Station, Tex., Sept., 1948. 62 pp. Free.

Planting, thinning, cultivation, insect control, defoliation, and the harvesting of cotton by mechanical means are comprehensively discussed. The history of mechanical cotton-strippers and mechanical pickers is related. Cleaning quality of cotton is said to be closely related to immaturity. The difficulty of cleaning long, fine cottons is said to be due to a relatively high percentage of immature fibers. Tests in 1944 and 1945 showed that mechanically picked Hi-bred, a short-staple variety, and Macha, a stormproof variety, graded from $\frac{1}{2}$ to $1\frac{1}{2}$ grades lower than the same varieties handpicked, but gave slightly stronger yarns. With Deltapine and Rogers Acala varieties, machine-picked cotton graded 1 grade lower than handpicked, but 1 grade higher than hand-snapped and machine-stripped cotton. Quality of yarn was not affected by the method of harvesting, except for a slight lowering of appearance-grade for longer and finer-fibered cottons. R. B. Evans

Text. Research J. Feb. 1949

Tariffs on Cotton Manufactures

Cotton manufactures. Summaries of Tariff Information, Volume 9. U. S. Tariff Commission, Washington, D. C., 1948. 224 pp. Free.

Data on tariff rates, domestic production and exports, and on quantity and value of imports are given for 62 types of cotton manufactures imported into the United States. Comments are given on the current export-import status of each item and on the present situation in the domestic industry involved.

Text. Research J. Feb. 1949 R. B. Evans

Cotton Utilization

Cotton counts its customers. Frank A. McCord. Memphis, Tenn., National Cotton Council of America. **Supplement no. 2. Apparel and household uses.** October, 1947. 14 pages. **Supplement no. 3. Industrial uses.** May, 1948. 16 pages. Free.

Data are presented on the quantities of cotton consumed for 116 apparel and household uses and for 24 major industrial uses during the years 1939–1946. An appendix gives sources of information.

Text. Research J. Feb. 1949 R. B. Evans

Cotton in the California apparel industry. Frank A. McCord and Raymond Steinbach, Jr. Memphis, Tenn., National Cotton Council of America, June, 1948. 19 pages.

California is now second only to New York City in production of women's, misses', and juniors' outerwear, and has style leadership in sportswear for both men and women. Consumption of cotton fabrics by California apparel manufacturers is said to be increasing. Advantages in use of cotton and needed improvements are stated. It is reported that cotton fabrics for apparel use need new weaves and designs, more brilliant dyes, improved softness and drape, noncrushable finishes, and improved dry-cleaning techniques. Suggestions for promotion and merchandising activities also are given. R. B. Evans

Text. Research J. Feb. 1949

World Cotton Production

Current world cotton situation: developments and prospects. Textile and Leather Branch, U.S. Dept. of Commerce. *Foreign Com. Weekly* **31**, 11, 12, 47 (June 19, 1948).

World production of cotton in 1947–48 will total nearly 25,000,000 bales compared with 21,600,000 bales in 1946–47 and 29,500,000 bales in 1938–39. World production of medium staples, 1 in. through 1/3/32 in., totaled 13,000,000 bales in 1947, which is 52% of total production of cotton as compared with 12,100,000 bales, 41% of total production of cotton in 1938. Long staples, $1\frac{1}{8}$ in. and longer, declined from 3,600,000 bales, or 12% of total in 1938, to 2,200,000 bales, or 9% of total in 1947. Short staples, less than 1 in., declined from 13,800,000 bales in 1938, 47% of total, to 9,700,000 bales, or 39% of total in 1947. World stocks of cotton declined from 25,000,000 bales on Aug. 1, 1946, to expected 14,500,000 bales on Aug. 1, 1948. Statistics by countries are given.

Text. Research J. Feb. 1949 R. B. Evans

Cotton Research Trends

Study of agricultural and economic problems of the Cotton Belt: Hearings before Special Subcommittee on Cotton of the Committee on Agriculture, House of Representatives, Part 2, pp. 879–1170, Oct. 10, 1947. Washington, U.S. Government Printing Office, 1948. Free. (*Cf.* TEXTILE RESEARCH JOURNAL **18**, 138, (Feb. 1948)).

This volume presents several statements by officials of the Department of Agriculture regarding current cotton research activities. According to H. W. Barre, H. D. Barker, and E. E. Berkley of the Bureau of Plant Industry, Soils, and Agricultural

Engineering, research findings are increasing the knowledge of factors affecting the quality of cotton and better cottons are being developed, about 50% stronger than the older varieties. According to Dr. Walter M. Scott, as a result of research at Southern Regional Research Laboratory, cotton can be made resistant to microorganisms and weathering, cotton fabrics can be made which are highly resistant to water, a test has been developed to measure immaturity in cotton fibers, and improved cotton tire fabrics have been developed. Increasing competition which cotton is encountering from synthetic fibers and paper also has been studied at the Southern Regional Laboratory. According to George R. Boyd, Charles A. Bennett, and William E. Meek of the Bureau of Plant Industry, Soils, and Agricultural Engineering, all operations in growing, harvesting, and processing cotton can be done by machines now available, but this equipment is feasible only for the western half of the cotton belt and must be adapted for use on small and hilly farms. According to P. N. Annand and R. W. Harned, Bureau of Entomology and Plant Quarantine, some of the newer synthetic organic insecticides such as DDT have given remarkable results in experiments on cotton and may indicate arrival of a new era in cotton insect control. Each of the statements noted is available separately as well as in the combined volume. R. B. Evans

Text. Research J. Feb. 1949

Cotton Textile Industry

Cotton textiles and the national economy. Claudius T. Murchison. *Textile Inds.* **112,** 123–8 (July 1948).

Although the number of cotton industry spindles declined from 37,900,000 in 1925 to 23,800,000 in 1947, the amount of cotton processed per active spindle was more than twice that processed in 1929, owing to greater efficiency and longer hours of spindle operation. Yardage of cotton goods available for civilians declined from 8,200,000,000 yds. annually during 1937 and 1939 to an average of 4,900,000,000 yds. annually during the period 1942–45. Sustained demand since then has been due to wartime shortage plus growth of population and slowness of foreign trade in recovering. Demand for cotton goods in the linen supply trade, in work uniforms, and styled women's apparel is said to be growing.

Text. Research J. Feb. 1949 R. B. Evans

Bibliography on Cotton

Cotton and cotton manufactures (basic information sources). L. W. Cain. Inquiry Reference Service, U. S. Department of Commerce, Washington, March, 1948. 10 pages. Free.

Current government publications, selected nongovernmental publications, directories, trade journals and services, and trade associations in the cotton and cotton manufactures field are listed.

Text. Research J. Feb. 1949 R. B. Evans

Alleged Darkening of Fabrics by Gold

Darkening produced on skin or fabrics by wearing gold jewelry. Marcel Ballay and Pierre Vogt. *Rev. mét.* **44**, 256–60 (1947) (through *Chem. Abstr.* **42**, 3298*f* (May 20, 1948)).

Complaints that gold jewelry soils linen began to be heard just after the war. Tests showed no difference between the new and prewar jewelry. The effects could not be attributed to skin secretions, since immersion of 18 carat gold plates in vinegar, 0.15% lactic acid, sorrel extract, broth, garlic and onion juice, and urine did not effect Au. Specimens of yellow, red, and pink Au were machined and were allowed to rub over more than 30 samples of fabrics. Fabrics were used either as received from the manufacturer or after washing with pure Castile soap and with a war-grade soap containing much mineral matter. All gold specimens behaved in the same manner. Darkening was caused by abrasion caused by fibers themselves, their sizing, or residual matters from the adulterated soap. No definite relationship was found.

Text. Research J. Feb. 1949

Finishing Agents and Serviceability of Rayons

The influence of various finishing agents on the serviceability of staple rayon shirt fabric. E. Wagner. *Melliand Textilber.* **28**, 65–8, 103 (1947); cf. *C.A.* **42**, 5680*i* (through *Chem. Abstr.* **42**, 6542*a* (Sept. 10, 1948)).

The results of various previously reported investigations are summarized and discussed. Cf. *C.A.* **40**, 4220[9].

Text. Research J. Feb. 1949

Fire Hazards

Jute, flax, and hemp. Special hazards and fire problems associated with the industry. A. S. Pratten. *Quart. Inst. Fibre Engrs.* **8,** No. 1, 1–19 (1948) (through *Chem. Abstr.* **42,** 4351*f* (June 20, 1948)).

A survey covering the origin of these fibers, fiber extraction, baling, storage, fiber processing, causes of fire, fire conditions, water absorption, fire-fighting technique, etc.

Text. Research J. Feb. 1949

Mercury Poisoning in Hat Factories

Neurological observations on ten cases of chronic industrial mercurialism. E. C. Vigliani and M. Pennacchietti. *Rass. med. ind.* **16,** 1 (1947); *Brit. J. Ind. Med.* **5,** 39 (1948); cf. *C.A.* **40** 5496[1] (through *Chem. Abstr.* **42**, 3967*b* (June 10, 1948)).

Over 100 cases of mercurialism occurred in 2 Italian felt hat factories in which the air contained much more than the 0.1 mg. Hg/cu. m. which is supposed to be tolerable. In 10 cases studied neurologically, the cerebral cortex and the extrapyramidal system were particularly involved. In addition to the dyskinetic and hyperkinetic phenomena, there were akinetic-hypertonic changes due to involvement of the globus pallidus, rarely mentioned in the literature.

Text. Research J. Feb. 1949

Hemp Production

Hemp—production and utilization. Anne L. Ash. *Economic Botany* **2,** 158–69 (Apr.–June 1948).

Growing, harvesting, marketing, and utilization of hemp are described. In 1943 in Illinois the cost per acre of producing hemp with a yield of 2.6 tons per acre was $55.02, about double the cost of producing corn. A total of 60,000,000 lbs. of line fiber was harvested in the U. S. during 1943 and 1944 under a wartime project which was curtailed as sisal and hemp became available.

Text. Research J. Feb. 1949 R. B. Evans

Percale Service Test

Serviceability of percale in girls' dresses. Dorothy Saville. *J. Home Economics* **40,** 457–8 (Oct. 1948).

Results of a service test of 23 percales in children's dresses are given. It was found that 80-square percales were worn and washed on an average of $\frac{1}{4}$ times more than those of lower counts before dresses were discarded. R. B. Evans

Text. Research J. Feb. 1949

Textile Petroleum

Petroleum chemicals in relation to the textile industry. E. S. Paice. *J. Soc. Dyers and Colourists* **64,** 237–44 (July 1948).

The theme of this paper is the parallelism between the production of man-made fibers and the production of organic chemicals from petroleum sources. The products obtainable from ethylene, propylene, and methane are shown on charts. The manufacture of products useful in textile processing, such as resins, detergents, and solvents are traced from the parent chemical sources.

J. A. Woodruff

Text. Research J. Feb. 1949

Plastics

Plastics for corrosion control. J. W. Shackleton. *Corrosion* **4,** 172–8 (1948) (through *Chem. Abstr.* **42,** 4791*h* (July 10, 1948)).

Cellulose plastic wrappings have given good service as pipe coverings, but are not sufficiently resistant to corrosion for general application. *Polyvinyl alcohol* is resistant to organic solvents, but is limited in application by its solubility in water. *Acrylic resins* (Lucite) have found extensive use in electroplating tanks, plating barrels, etc., but their chemical and physical properties limit their use for corrosion control. *Vinylidine chloride* (Saran) has been used for pipe tor handling chemicals. These resins can be used as coating materials in the form of emulsions, but may produce slight amounts of HCl, sometimes causing metal corrosion. *Vinyl chloride resins* are applied (as coatings) in dispersion form and then fused into continuous films at about 350°F. These coatings are widely used in the electroplating industry; as compared with the vinylidine chloride coatings, these films are somewhat more stable and easier to apply, but are not as resistant to chemical attack. *Nylon* coatings are applied from solutions in alcohol and water, or of certain phenols (including cresylic acid), but the more chemically resistant forms of nylon are not generally recommended for coatings for the production of films. Nylon films are useful for a variety of chemicals other than mineral acids. *Polythene* (polyethylene) films can be applied from hot chlorinated hydrocarbon solutions, or by flame-spraying, but difficulty has been encountered in securing satisfactory films by the latter method. A method has been developed for applying polythene sheets for tank lining. Only a very few chemicals have any effect on polythene except the chlorinated hydrocarbons and a few other hydrocarbons. Over a long period of time, oils and greases may swell polythene somewhat. Acetic acid appears to penetrate polythene films. No plasticizer is required in polythene films. Polythene has extremely high impact strength and outstanding electrical properties. *Teflon* (a polymer of tetrafluoroethylene) is outstanding in chemical resistance for packings, gaskets, pipes, fittings, etc. The only chemicals known to attack Teflon are molten alkali metals and free F gas at 300°F. It has a service temperature range from −70° to 550°F. It can be molded and extruded, but it is not soluble and cannot be cemented by any means yet discovered. A suspensoid-type coating is being developed.

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Pulp for Viscose

The manner in which native cellulose reacts. R. Bartunek *Cellulosechemie* **22,** 137 (1944) (through *Chem. Abstr.* **42,** 4341*d* (June 20, 1948)).

An addendum (cf. *C.A.* **39,** 2401[5]). Bartunek was apprised by the Phrix-Werke A.G. (Hamburg) that they had found it technologically feasible to convert a pine sulfate pulp (which had not undergone prehydrolysis or subsequent treatment) into viscose by immersion press mercerization, xanthation, and solution.

Text. Research J. Feb. 1949

Circular Loom

New French circular loom used on rayon. H. R. Mauersberger. *Rayon and Synthetic Textiles* **29,** 81–2 (Sept. 1948).

The circular loom has been used on very fine rayon yarns and fabrics. Limitations are its width, patterning, and filling replenishment. Because it employs only 2 to 5 harnesses, its use is limited on 8-harness satins. Greatest utility will probably be in plain weave staple-width fabrics. L. A. Fiori

Text. Research J. Feb. 1949

New Loom

A loom to weave chenille weft. Anon. *Textile Weekly* **42,** 394, 396, 398 (Aug. 20, 1948).

A new 2-process method of making chenille Axminster carpets based on the newly developed Fielding automatic gripper chenille loom. This system can take a 200-lb. filling supply, select and use up to 50 colors for a Jacquard pattern, and pass on to the Axminster carpet loom proper an unlimited supply of perfect filling yarn or "fur." Illustrated.

Text. Research J. Feb. 1949 L. A. Fiori

Electrical Control for Looms

Electro-magnetic control applied to Staubli dobbies. Anon. *Silk J. & Rayon World* **25,** 48 (Aug. 1948).

The process of electro-magnetic control for dobbies on the S. W. M. sample hand loom has now been applied to the Staubli dobbies fitted to power looms. The device is described in detail. L. A. Fiori

Text. Research J. Feb. 1949

New Roving-Frame Stop Motion

Electric stop motion. Anon. *Saco-Lowell Bull.* **20,** 33–4 (July 1948).

Details of a roving-frame electric stop motion which operates through the contact of a small wire fastened to the underclearer latch with a rod which supports the apron rolls and is grounded to complete the circuit are given. Illustrated. L. A. Fiori

Text. Research J. Feb. 1949

Redrawing Machine for Nylon

A redrawing machine for nylon. Anon. *Text. Mercury and Argus* **119,** 267–8 (Aug. 27, 1948).

A new type of spindleless redrawing machine especially designed to meet the exacting demands of nylon and the stronger types of continuous-filament yarns at the highest possible speeds. L. A. Fiori

Text. Research J. Feb. 1949

Vertical Opener

The new Saco-Lowell vertical opener. Anon. *Saco-Lowell Bull.* **20,** 35–43 (July 1948).

A detailed discussion, supplemented by illustrations, of the design, construction, and features of this new opener, and also a general description of vertical-opener operating principles. L. A. Fiori

Text. Research J. Feb. 1949

Spinning and Twisting Rings

Spinning and twisting rings. R. S. Audley. *Fibres* **9,** 307–8 (Aug. 1948).

A review of spinning and twisting ring developments and specifications. L. A. Fiori

Text. Research J. Feb. 1949

Fluid Drive in Textile Machinery

Fluid drive adapted to textile machinery. Anon. *Rayon Text. Mo.* **29,** 91 (July 1948).

The fluid-drive principle, successfully used in automobiles, is now being applied in driving ring spinners, carding machines, and calenders. For mechanical draft drives, adjustments producing minute variations in speed are possible.

Text. Research J. Feb. 1949 L. A. Fiori

Stain Removal

The washing process. IV. Removal of oily stains considered as a displacement phenomenon. W. Kling. *Melliand Textilber.* **28,** 197–9 (1947); *Chimie & industrie* **58,** 579 (1947); cf. *C.A.* **41,** 3972*h* (through *Chem. Abstr.* **42,** 4353*g* (June 20, 1948)).

Removal of oily stains by washing consists of displacing the oil from the surface of the substrate by the aqueous detergent solution. A study is made of the forces involved in this action. Practical results agree with theoretical deductions.

Text. Research J. Feb. 1949

Waste Duster

An improvement on the No. 11 and No. 12 dust and waste extractor. Anon. *Saco-Lowell Bull.* **20,** 4–5 (Feb. 1948).

Instructions are given for the modification of existing waste extractors in order to prevent the collection of waste in the housing, from which it escapes into the cotton. L. A. Fiori

Text. Research J. Feb. 1949

Water-Repellency

Imparting water-repellency to textiles by chemical methods: A review of the literature. H. A. Schuyten, J. David Reid, J. W. Weaver, and John G. Frick, Jr. TEXTILE RESEARCH JOURNAL **18,** 396–415 (July 1948); 490–503 (Aug. 1948).

The literature relating to the water-repellency of textile materials was surveyed for those articles and patents dealing with the production of this property by chemical methods. The 332 pertinent references found have been abstracted and classified on the basis of the type of compound used to impart water-repellency. No attempt has been made at critical evaluation. Reactions, where known, have been described with the aid of equations. Additional references for collateral reading are given. An index which has been compiled of the chemical water-repellent agents proposed has been published by the U. S. Department of Agriculture as Research Publication AIC-179. Authors

Text. Research J. Feb. 1949

Wool-Manufacturing Industry

Fewer machines—greater output: The wool industry. Edwin Wilkinson. *Textile Inds.* **112,** 136–8 (July 1948).

Although the number of spindles and looms in the wool industry has been declining since 1919, production of wool apparel fabrics was at a peak in 1947. Development of the American system of spinning; improvement of French spinning, as well as of electronic controls; and improved plant construction, etc., give promise of greatly increased efficiency. R. B. Evans

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